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Coping with E-Waste: Prospects of E-Waste Circular Economy Within the GCC: Analyzing the Legal Framework on Recycling of E-Waste Within the GCC

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COPING WITH E-WASTE

PROSPECTS OF E-WASTE CIRCULAR ECONOMY WITHIN THE GCC: Analyzing the Legal Framework on Recycling of E-Waste Within the GCC

A dissertation submitted to the faculty in partial fulfillment of the requirements for the degree of Doctorate in Judicial Studies (S.J.D.) in environmental law at the Elisabeth Haub School of Law at Pace University

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Abstract

The GCC has experienced rapid population growth and urbanization in the last 40 years. The rise in population has caused a surge in e-waste within the GCC countries. Electronic waste poses severe health and environmental risks, calling for the adoption of a circular economy where e-wastes are converted into valuable products through recycling. However, achieving a circular economy requires a robust legal framework, technologies and policies as practiced globally. The Global E-waste Monitor has traced e-waste generation in the GCC countries since 2014. One critical finding is that the e-waste generation has surged with population growth, urbanization and the advancement in technology that encourages the use of new electronic devices and dumping of electrical and electronic equipment considered obsolete. The end-of-life of electronic devices has been shortened due to the population's technological advancement and increased affordability of electrical and electronic equipment (EEE). Drawing on the literature, this study explored whether the GCC has an adequate legal framework to enable a circular economy by recycling e-wastes rather than dumping them in landfills. The research sought to find the best practices on e-waste recycling globally and compare them to the GCC settings. The study examined the adequacy of the GCC legal framework and the ability to achieve a circular economy using a qualitative case study methodology where e-waste management policies and legislation are examined in different GCC states to understand e-waste management in the region. A descriptive study design was used to explore the current GCC states' legal frameworks and e-waste management status using primary and secondary data sources. The data was collected from the GCC states government documents by examining the constitutions, published environmental laws and policies, government websites and other secondary sources like journal articles and international organizations' reports. The study established that achieving a circular economy in the GCC is minimal because of limited laws

regulating e-waste recycling. Further, the region has not adopted the best technology to recycle e-wastes as seen in European settings. The inadequate legal framework should be addressed to ensure proper e-waste recycling to achieve a circular in the GCC countries.

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List of Abbreviations

GCC-Gulf Cooperation Council
GEWMS-Global Electronic Waste Management and Security
MSW-Municipal Waste
WEEE-Waste Electrical and Electronic Equipment
HCFC-Hydrochlorofluorocarbons
CFC-Chlorofluorocarbons
ODS- Ozone-Depleting Substances
LCD- Liquid Crystal Displays
PCBs- Printed Circuit Boards
REEs- Rare earth elements
CENELEC- European Electrotechnical Committee for Standardization (CENELEC)
WEEELABEX-WEEE Label for Excellence Responsible Recycling (R2) Certification
EPEAT-Electronic Product Environmental Assessment Tool
EEE-Electrical and Electronic Equipment
CN-Combined Nomenclature
PACE-Platform for Accelerating the Circular Economy
COP- Conference of Parties
ESM-Environmentally Sound Management
POPs-Persistent Organic Pollutants
EIA-Environmental Impact Assessment

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CHAPTER ONE:

GENERAL INTRODUCTION AND CONTEXT

1.1 Research Background

Gulf Cooperation Council (GCC) comprises six countries, including the United Arab Emirates (UAE), Bahrain, Qatar, Saudi Arabia, Kuwait, and the Sultanate of Oman.[1] The GCC countries have been experiencing a rise in population and urbanization levels over the last forty years.[2] They have increased the standard of living of individuals and augmented electronic waste (E-waste) to optimized levels.[3] E-wastes include waste materials made up of ferric and non-ferric minerals, glass, electronic boards, iron, steel, printed circuit boards, batteries, chargers, and others.[4] Further, e-wastes contain hazardous materials like flame retardants, cadmium, mercury, hexavalent chromium, lead, and others in more than permissible levels. E-waste causes harm to the natural environment and pollutes the surroundings in which the e-wastes are dumped.[5]

The Global E-waste Monitor has traced global e-waste generation since 2014. In 2014, the report by the Global E-waste Monitor indicated that global e-waste generation reached 41.8 million tons.[6] The subsequent report indicated that the world generated total e-waste amounting to 44.7

[1] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016.
[2] Santoro, Carlo, Fernando Benito Abad, Alexey Serov, Mounika Kodali, Kerry J. Howe, Francesca Soavi, and Plamen Atanassov. "Supercapacitive microbial desalination cells: new class of power generating devices for reduction of salinity content." *Applied energy* 208 (2017): 25-36.
[3] Ouda, Omar KM, S. A. Raza, A. S. Nizami, M. Rehan, R. Al-Waked, and N. E. Korres. "Waste to energy potential: a case study of Saudi Arabia." *Renewable and Sustainable Energy Reviews* 61 (2016): 328-340.
[4] Khatib, Imad A. "Municipal solid waste management in developing countries: Future challenges and possible opportunities." *Integrated waste management* 2 (2011): 35-48.
[5] Allam, Hossam, and Simon Inauen. "E-waste management practices in the Arab region." *Cairo, Egypt: Centre for Environment and Development for the Arab Region* (2009).
[6] Baldé, C.P., Wang, F., Kuehr, R., Huisman, J. (2015), The global e-waste monitor – 2014, United Nations University, IAS – SCYCLE, Bonn, Germany.

Mt.[7] In 2019, the e-waste generated globally rose to 53.6 Mt, indicating a trend of a steady rise in the production of e-waste globally.[8] On the other hand, GCC countries produced 94 million tons of e-waste in 2015 and were expected to reach 120 million tons by 2020.

As a result of the global rise in e-waste generation, the concerns related to effective e-waste management has increased among the countries and increases the need to implement adequate laws and regulation for the proper disposal and management of e-waste.[9] For example, the United Arab Emirates serves a population of 5.9 million, which generates 17.2 per capita e-wastes (kg) every year and 101 thousand tons of e-waste every year. Bahrain recorded 12.9 per capita e-wastes (kg) and a total of 15 thousand tons of e-waste per year by serving a population of 1.2 million. On the other hand, Oman recorded 14 per capita e-wastes (kg) and 46 thousand tons of electrical waste annually by serving a population of 3.3 million.[10] Global Electronic Waste Management and Security (GEWMS) survey found that 41.8 million metric tons of e-waste were produced in 2004. The electronic waste was expected to reach 50 million metric tons Mt. by 2018 globally. Other GCC member states, such as Kuwait and UAE, produced 17.2 kg e-wastes per year. Despite its high population, Saudi Arabia generated the lowest e-waste per capita of 12.5 kg in 2014 among GCC countries. However, the trend has since changed since Saudi Arabia was a leading e-waste generator as of 2019.[11]

[7]Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann,P. : The Global E-waste Monitor – 2017, United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Vienna.

[8] Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam.

[9] Sandra Alvarado Barrero, Guidelines for the definition of a legal framework on electronic waste from Information and Communication Technologies. Geneva, 2017.

[10] Balde, Cornelis P., Feng Wang, Ruediger Kuehr, and Jaco Huisman. "The global e-waste monitor 2014: Quantities, flows and resources." (2015).

[11] Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research

The high incidence of e-wastes generation causes harm to the natural environment by polluting the atmosphere, soil, and water. For example, lead is generated from printed circuit boards, gaskets present in computer monitors that pollute soil and negatively impact the good health conditions of the individuals. It damages the functioning of the central nervous system and impacts the brain development of children. On the other hand, cadmium, mercury, Hexavalent chromium produced from semiconductors, switches, galvanized steel plates, and others cause neural damage, skin disorders, DNA damage, and other harmful effects on health.[12] In addition to this, other issues such as improper disposal of e-waste, high growth of population, increased use of electronic gadgets, and limited landfills are faced by GCC countries, causing challenges in the reduction and disposition of the e-waste. As a result, e-waste management has become a challenging task for the governing bodies in every country.

It has become essential to regulate the ways or processes in which e-wastes are discarded, managed, and disposed of so that less harm is caused to the environment. In Kuwait, for instance, landfills serve as a medium to dispose of electronic waste as there is no other developed method to dispose of the e-waste separately. The country has a total of 18 landfills in which 14 landfills are closed. A significant amount of the e-wastes are dumped in the four landfills that are currently working.[13] The limited options to discard e-waste safely in Kuwait causes severe health and environmental issues resulting from toxic gases in landfill sites. About 2.51 million tons of MSW were expected to be generated in Kuwait by 2020, with a daily average municipal waste of 1.4 kg

(UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam.

[12] Rao, L. Nageswara. "Environmental impact of uncontrolled disposal of e-wastes." *International Journal of ChemTech Research* 6, no. 2 (2014): 1343-1353.

[13] Al-Anzi, Bader S., Abdul Aziz Al-Burait, Ashly Thomas, and Chi Siang Ong. "Assessment and modeling of E-waste generation based on growth rate from different telecom companies in the State of Kuwait." *Environmental Science and Pollution Research* 24, no. 35 (2017): 27160-27174. P.2.

per individual.[14] The wastes produced in Kuwait consist of e-wastes, organic wastes, metals, plastic, glass, and others. The capacity of the landfills is 45.5 km2 which is projected to reach 60 km2 by the end of the year 2025. Moreover, 76% of the wastes generated in Kuwait could be recycled, and the remaining 24% could be discarded in landfills.[15]

On the other hand, Bahrain generates 1.2 million tons of wastes annually. The waste is discarded at Askar, a landfill occupying 700 acres. The landfill is located close to urban regions, thus causing environmental risks to the natural surroundings and undermining the healthy living conditions of the individuals. As a result, waste to energy plants has been established in Bahrain to support the only landfill present in the country. Other initiatives, such as the development of recycling points for wastes like metals, cardboard, paper, and plastics, recycled and directly have been institutionalized to collect waste that could be sent to the recycle centers. Additionally, a German firm and the "Mother and Child" Welfare Society have established recycling points to recycle the ferric and non-ferric wastes.[16]

The generation of e-waste in Bahrain is substantially high, while its awareness among the citizens is low. Moreover, there are no concrete laws regarding the management, reduction, collection, or disposing of e-waste, causing significant issues related to e-waste management in Bahrain.[17] However, the condition of e-waste management in Saudi Arabia is not different since it lacks specific laws on e-waste management. The Kingdom generates 15 million tons of wastes

[14] Al-Jarallah, Rawa, and Esra Aleisa. "A baseline study characterizing the municipal solid waste in the State of Kuwait." *Waste Management* 34, no. 5 (2014): 952-960.
[15] Alsulaili, Abdalrahman, Bazza AlSager, Hessa Albanwan, Aisha Almeer, and Latifa AlEssa. "An integrated solid waste management system in Kuwait." In *5th international conference on environmental science and technology*, vol. 69, no. 12, pp. 54-59. 2014.
[16] Al Sabbagh, Maram K., Costas A. Velis, David C. Wilson, and Christopher R. Cheeseman. "Resource management performance in Bahrain: a systematic analysis of municipal waste management, secondary material flows and organizational aspects." *Waste Management & Research* 30, no. 8 (2012): 813-824.
[17] Alameer, Hasan. "Assessment and evaluation of waste electric and electronics disposal system in the middle east." *European Scientific Journal* 10, no. 12 (2014).

yearly with a 1.4 kg contribution of waste generation by each individual each day.[18] The country accounts for only a 10% to 15% recycling rate which results from the lack of awareness about e-waste management. The Governing body in Saudi Arabia has proposed a law related to waste management, but there are no proper processes to enforce the e-waste rulings.

The Sultanate of Oman produces 1.2 kg of wastes per individual each day with 1.7 million tons yearly. The country does not possess efficient recycling entails and all the wastes generated in different regions are dumped or disposed of in landfills. Oman has more than 350 dumpsites that the municipal workers manage. At present, Oman has not established any legal framework to manage e-waste.

Qatar, one of the rising economies, generates 2.5 million tons of wastes with 1.8 kg per individual each day. All the generated wastes are disposed of in landfills. Notably, the governing body in Qatar has established a waste management plan that recycles 38% of waste and contributes towards sustainable environmental protection. Qatar does not possess any specific laws regarding e-wastes management or awareness and may develop shortly. However, among all the GCC countries, the United Arab Emirates is the only country with proper steps towards reducing e-waste through an e-waste management program. The country has established the ecoATM to reduce the issues related to e-waste. The governing body has started an educative initiative to spread awareness among the people regarding proper e-waste disposal.[19] Additionally, Tadweer has been established in Abu Dhabi as the Waste Management Center to provide waste classification and management guidelines. The country has developed recycling facilities for appropriate discarding

[18] Nizami, A. S., O. K. M. Ouda, M. Rehan, A. M. O. El-Maghraby, J. Gardy, A. Hassanpour, S. Kumar, and I. M. I. Ismail. "The potential of Saudi Arabian natural zeolites in waste-to-energy technologies." *Energy* (2015).

[19] Alghazo, Jaafar, Omar KM Ouda, and Ammar El Hassan. "E-waste environmental and information security threat: GCC countries vulnerabilities." *Euro-Mediterranean Journal for Environmental Integration* 3, no. 1 (2018): 13.

of e-wastes and prohibits throwing of electronic devices like computers, mobile phones, and others in regular garbage bins

To reduce the adverse environmental and health effects resulting from the inappropriate disposal of e-waste, the governing bodies in Gulf countries have introduced specific directives and rulings to manage e-waste properly. The measures help reduce the harmful effects caused by improper disposal of e-waste in the open or landfills by providing a regulatory framework. For example, the Supreme Council (6th session, Muscat Summit, 1985) has introduced laws and regulations related to e-waste disposal by all the GCC nations.[20] The rulings provided by the Muscat Summit will help enhance the environmental conditions and significantly reduce pollution levels to a minimum. Additionally, Biological Treatment Standard 2012 lays down guidelines on the disposal of e-waste and conserving natural surroundings. It consists of several sub-divisions that define rulings and laws about all aspects of the environment, such as air, soil, and water leading to an effective ecological balance. Besides, the establishment of Environmental Standards on Material Recovery and Recycling of Waste 2012 has been done to safeguard the natural surroundings against the ill-effects of inappropriate disposing of electronic wastes.

Other measures, such as General Environment Protection Law, have been institutionalized by the Supreme Council to resolve issues on environmental protection. The initiatives help in reducing the pollution levels generated by different human activities.[21] Equally, the directives laid down by General Environment Protection Law have encouraged other countries to implement effective measures to control pollution generating factors and reduce pollution levels. In addition

[20] Iqbal, Mehreen, Knut Breivik, Jabir Hussain Syed, Riffat Naseem Malik, Jun Li, Gan Zhang, and Kevin C. Jones. "Emerging issue of e-waste in Pakistan: a review of status, research needs and data gaps." *Environmental pollution* 207 (2015): 308-318.
[21] Ifegbesan, Ayodeji Peter, Biodun Ogunyemi, and Isaac T. Rampedi. "Students' attitudes to solid waste management in a Nigerian university." *International Journal of Sustainability in Higher Education* (2017).

to this, the Supreme Council has also framed Common Law for the Environmental Assessment of Projects to protect the natural surroundings, resources, and reserves.[22] The law propagates that all the measures that could help restructure or re-establish the natural environment must be implemented so that the harmful implications of pollution are reduced to a minimum. It emphasizes installing Standard on Waste Transportation as per the directives given by the Presidency of Metrology and Environment to classify wastes into different categories and introduce the treatment process accordingly.

Additionally, the Supreme Council established the Common Reference Law for Controlling the Ozone Depleting Materials to create awareness about the harmful impacts of improper e-wastes disposals. It will provide learning about the damage and depletion caused to the natural surroundings because of the emission of hazardous substances from the improper e-wastes sites. Furthermore, the GCC member states have approved the Green Environment Initiative that promotes the GCC Environment Action Pact and implements a plan for the regulation of e-waste management. To this end, the Supreme Council organized the 28th Session, Doha, in December 2007 so that all GCC members could be instructed about implementing the proper e-waste management framework. It was to help the GCC nations to meet their targets of reducing pollution and conserving natural resources and the environment effectively. Under the Green Environment Initiative introduced by Doha Session, a GCC Environment Action Pact was laid out to develop measures for reducing high pollution levels. The Action Pact posited that preserving and conserving the environment for effective human growth and development is essential.[23]

[22] Gill, Nick. "Landscapes of Toxic Exclusion: Inmate Labour and Electronics Recycling in the United States." In *Carceral Spaces*, pp. 105-120. Routledge, 2016.
[23] Daum, Kurt, Justin Stoler, and Richard J. Grant. "Toward a more sustainable trajectory for e-waste policy: a review of a decade of e-waste research in Accra, Ghana." *International journal of environmental research and public health* 14, no. 2 (2017): 135.

1.2 Problem Statement

E-wastes are highly complex as they contain various materials, metals, minerals, and substances, making them difficult to handle and discard. E-wastes contain heavy metals such as lead, cadmium, mercury, and others that cause high destruction to the natural environment. Additionally, e-wastes contain organic pollutants such as polybrominated diphenyl ethers, polychlorinated biphenyls, and more than 1000 different materials that are highly toxic.[24] These substances expose toxic chemicals to the atmosphere, soil, and water that individuals consume in dust inhalation, dietary intake, and others. E-waste pollution may also result in mental growth impairment and negative implications such as high blood pressure, central nerve disturbance, and kidney damage.[25]

The problem in this research is not just the adverse effects of e-waste and how to reduce pollution in the GCC member states. Instead, this paper looks at how the GCC member states can turn the e-wastes into an economically viable product. One way of achieving a circular economy within the GCC is through recycling. Notably, achieving a circular economy involves implementing several principles and laws are at play. Equally, the best available technology plays a significant part in ensuring that e-wastes are appropriately recycled and the maximum economic value is derived from the wastes. Therefore, this research will find the best practices on e-waste recycling and compare them to those within the GCC. As a solution to the e-waste challenge, this research investigates the adequacy of the legal framework on e-wastes within the GCC. The paper follows the environmentally sound management (ESM) approach. The concept of environmentally sound management of e-wastes allows states to internalize the externalities of e-wastes. E-wastes'

[24] Borthakur, Anwesha. "Generation and management of electronic waste in the city of Pune, India." *Bulletin of Science, Technology & Society* 34, no. 1-2 (2014): 43-52.
[25] Zeng, Xianlai, Congren Yang, Joseph F. Chiang, and Jinhui Li. "Innovating e-waste management: From macroscopic to microscopic scales." *Science of the Total Environment* 575 (2017): 1-5.

sound management reduces pollution (environmental externality) by developing proper procedures that turn the wastes into economically viable materials. This process is termed a circular economy of e-wastes which involves the production, consumption, disposal, technology, and legal framework as variables.

From the background, one can readily tell that the GCC stands a higher chance of achieving a circular economy due to its high production of e-wastes. Although these high levels of e-waste pose environmental threats and risks to humans, the concern of this research is how laws can be used to reduce pollution and enhance recycling. This research studied the type of laws available at the global, regional, and national levels. The study hypothesized that a legal framework specific to e-waste management is essential in enhancing the recycling of e-waste. Similarly, this research hypothesized that only technologically enhanced recycling could enable the GCC to maximize the economic benefit of e-wastes. Without the best available technology, most precious metals can be lost to poor recycling. Equally, the best available technology ensures that the pollution levels of the wastes are reduced to a minimum. Thus, this research studied landfilling as a method of e-waste management and its effect on soil and air pollution.

Similarly, incineration was equally studied, primarily in recycling copper from waste electrical and electronic wastes. Both landfilling and incineration are studied as environmentally unsound ways of managing e-wastes due to their high pollution levels. GCC countries should work on a common platform to develop and implement measures related to disposing and recycling e-waste. The strategy should also involve formulating laws, spreading awareness, and exercising control over improper discarding of e-waste. For example, new e-waste management and security systems must be formed to reduce the adverse environmental implications of e-wastes and increase economic value by extracting valuable materials from e-waste. Initiatives such as Extended

Producer's Responsibility (EPR) must be introduced by the competent authorities of different GCC members to promote proper recycling processes by the public and private enterprises. In addition, the GCC member countries must establish state-of-the-art recycling plants to record the total e-waste generated, the quantity of e-waste recycled, and the volume of e-waste dumped in landfills.

1.3 Aims and Objectives

The study's main objective is to research the possibility of an e-waste circular economy within the GCC member states. The research aims to identify global best practices in e-waste recycling and compare them with the practices within the GCC member states. The practices include the legal framework on e-wastes, environmental law principles including ecologically sound management of e-waste, and the best available technology in e-waste recycling.

The research also aims at assessing the adequacy of the environmental laws, e-waste management practices, and current technology on recycling within the GCC. This research highlights the different laws that GCC member states have enacted and their relevance in regulating e-wastes. Lastly, this research aims at analyzing the data on e-wastes globally and within the GCC from 2014 to 2019. The level of e-wastes generated will determine whether there are sufficient raw materials in terms of e-waste for recycling. E-waste circular economy is dependent on high waste generation, population, and high consumption levels for electrical and electronic equipment. This research seeks to study such trends and whether they favor the recycling of e-waste within the GCC member states.

1.4 Research Questions

i. Does the GCC have an adequate legal framework for the management of e-waste?

ii. Are there enough raw materials in terms of e-waste that can be recycled within the GCC member states?

iii. Can the GCC achieve a circular economy that will turn e-wastes into profit by recycling valuable materials?

1.5 Significance of the Study

The study analyzes various aspects associated with the management of e-waste in GCC countries. It will help the governments of the GCC member states, researchers, private sector, investors, organizations dealing with environmental policies, and students studying the aspects of e-waste management. The research aims to demonstrate how best practices in e-waste management can lead to the minimization of pollution caused by e-waste and the maximization of the value of recoverable materials from e-wastes to realize their economic value through recycling. Specifically, this study will help researchers examine the e-wastes disposal techniques and practices adopted by the GCC countries. Consequently, analysis of the management practices will help tackle the pollution effect of e-wastes and establish an economic balance by reducing the harmful effect of improper e-waste disposal. Notably, the discussion on e-waste recycling will help formulate recycling laws and policies for the GCC countries that do not have any legal framework. Besides, this research will contribute to understanding the best available technology, market growth, and niches of waste electrical and electronic equipment (WEEE) within the GCC. It will help understand the market value of specific materials recoverable from waste electrical and electronic wastes. The study also examines the e-waste generation at a global level to identify practices related to effective e-waste management that has increased among the countries.

1.6 Research Methodology

A research methodology is considered the research process that helps the researcher collect all the reliable facts based on the research problem to answer the research question effectively. Research methodology is commonly divided into qualitative and quantitative, where the qualitative approach focuses on description, exploration, meanings, and interpreting certain social

phenomena. The choice of the research methodology relies on the research question and assumptions on the nature of knowledge and approaches through which that knowledge can be obtained. The present research explores e-waste recycling in the GCC to gain insights into the region's e-waste circular economy. Therefore, the research is both descriptive and explanatory, leading to a multifaceted qualitative methodology to examine the e-waste problem, waste disposal, and the effectiveness of e-waste management practices in the Gulf countries. This research uses several techniques and approaches to ascertain the different factors necessary to effectively evaluate the usefulness of e-waste management practices and legislation in GCC countries.

The study uses a qualitative case study research methodology where e-waste management and laws are examined in different GCC countries to compare the e-waste management strategies in the region. The qualitative case study method relates to a qualitative research approach that thoroughly explores the complexity and uniqueness of a particular subject, policy, or program from multiple perspectives to understand meanings, practices, or activities. In this research, the e-waste recycling and laws in various GCC countries are examined through descriptive analysis to understand the e-waste circular economy in the GCC.

This study used primary and secondary sources to collect data on e-waste recycling in the GCC states. The published data used in this research was collected from various government documents such as environmental protection policies and laws. Other sources included books, research reports, and websites, and journal articles. The sources were obtained through a desktop search using keywords; e-waste in the GCC, GCC member states e-waste, Basel Convention, hazardous wastes, and e-waste recycling. Other open access journals and books relating to e-waste management in the GCC were obtained from Google Scholar search, followed by in-depth content analysis to identify themes associated with e-waste recycling in the GCC countries.

The GCC government websites on environmental protection and environment ministries were critical primary sources for this study since they offered primary and secondary data on the steps taken by the GCC nations to manage electronic wastes. For instance, data was obtained from Oman, Saudi, UAE, Qatar, and Bahrain's ministry of environment websites to understand e-waste management in the GCC. Other sources of primary data utilized during the research included the countries' constitutions and environmental laws. For example, the Saudi General Environmental Regulations and Rules for Implementation were used to analyze the environmental protection provisions related to e-waste management in the Gulf state.

Additionally, the research analyzed 25 reports on e-wastes authored by the United Nations Environmental Program (UNEP); or its affiliate organizations including the Global E-waste Monitor; Step initiative; Platform for Accelerating the Circular Economy (PACE); International Labour Organization (ILO); the International Telecommunication Union (ITU); the United Nations Industrial Development Organization (UNIDO); the United Nations Institute for Training and Research (UNITAR); the United Nations University (UNU), and the Secretariat of the Basel and Stockholm Conventions. These reports, alongside 200 open access journals, 100 open-access textbooks, and 15 Ph.D. theses, were analyzed and used to develop different chapters in this research.

Equally, this study also focused on collecting data on e-wastes generated globally and within the GCC member states. The research used secondary data collection methods that were available from the reports by different organizations including the United Nations Environmental Program (UNEP); or its affiliate organizations including the Global E-waste Monitor; Step initiative; Platform for Accelerating the Circular Economy (PACE); International Labour Organization (ILO); the International Telecommunication Union (ITU); the United Nations

Industrial Development Organization (UNIDO); the United Nations Institute for Training and Research (UNITAR); the United Nations University (UNU), and the Secretariat of the Basel and Stockholm Conventions. The data was recorded in figures and tables and used for comparative studies and analysis.

1.7 Research Approach

The research approach is a process that helps the researcher to collect the relevant data about the research topics by understanding the research problem. It mainly includes two aspects: qualitative and quantitative research approaches to collect and analyze the data. The present study demonstrates how best practices in e-waste management can lead to the minimization of pollution caused by e-waste and the maximization of the value of recoverable materials from e-wastes to realize their economic value through recycling. Specifically, this study will help researchers examine the e-wastes disposal techniques and practices adopted by the GCC countries. As a result, the study mainly focuses on a descriptive study design that uses literature review to study laws, policies, and management initiatives concerning e-wastes in the GCC countries. The descriptive study design systematically and accurately describes facts relating to e-waste management in the GCC.

1.8 Thesis Structure

Chapter 1: General Introduction and Context

This section mainly includes an overview of e-waste as a challenge in the Gulf countries and a potential for economic benefit. Chapter one gives the background of waste electrical and electronic equipment. It highlights the steady rise in the global rate of e-waste generation. The high incidence of e-wastes causes harms to the natural environment by polluting the atmosphere, soil, and water. The chapter discusses the need to curb pollution by implementing proper waste

management practices. After the background, the chapter develops the research problem, objectives, research questions, methodology, and approach.

Chapter 2: Recycling Technologies for E-wastes

This chapter discusses the best available technology for e-waste recycling. It starts by distinguishing environmentally sound technologies and those that are environmentally unsound. Chapter two isolates and discusses incineration as one of the environmentally unsound practices. Incineration leads to the loss of the plastic components of e-wastes and pollutes the air and soil. The fumes coming out of incinerators are equally harmful to human health. Besides, the chapter discusses modern technology used to recycle e-waste. Different products are recycled differently since their assembling vary. This chapter discusses how components of e-wastes such as batteries, plastics, precious metals, and rare earth metals are recovered with minimal pollution to the environment.

Chapter 3: International Environmental Law Principles & Standards of E-Waste Management

This chapter focuses on the international environmental law principles that form the foundation of e-waste laws and management policies. It discusses the prevention and precautionary principles, cooperation, no harm principle, proximity principle, and extended producer responsibility (EPR). It also discusses the different standards that have been developed by the European Union (EU) and the United States of America to help manage e-waste. Among the standards, this chapter analyzes the European Electrotechnical Committee for Standardization (CENELEC), WEEE Label for Excellence (WEEELABEX), Responsible Recycling (R2) Certification, Electronic Product Environmental Assessment Tool (EPEAT), and Swiss SENS/SWICO Technical Standard. These standards seek to minimize hazardous substances in

electrical and electronic equipment, thus lowering the risks of e-waste to the environment and human health.

Chapter 4: Global Trends in E-Waste Production and Management

This chapter looks at what it takes to discover the economic value of e-waste. The analysis in this chapter starts by discussing the steps of quantifying e-wastes. The initial stage involves monitoring the sales and consumption of electronics at the market entry phase. Then the electronics are to be monitored through the stock phase, where they undergo their residential lifetime. After the electronics become obsolete to the last owner, they are discarded and become e-waste. Data from all these stages have to be collected and harmonized at the municipal level if any progress in waste management is to be made. After that, the collection of e-waste begins. Some e-wastes may be collected from the official take-back system through the Extended Producer Responsibility. Other e-wastes may find themselves mixed with other household wastes and either go into landfills or municipal incinerators. Equally, other e-wastes may be handled outside the official take-back system, and they remain primarily unaccounted for municipally and internationally. In this dynamic flow of e-wastes, this chapter employs tables and figures to discuss the global value of e-wastes and the trends in e-waste generation and recycling.

Chapter 5: International Treaties on Electrical and Electronic Waste

This chapter considers the international, regional, and multinational treaties where the GCC member states are parties and comparative regional treaties. The first section discusses international conventions such as the Basel Convention, Stockholm Convention, Minamata Convention, Rotterdam Convention, and the Montreal Protocol. The second section discusses regional treaties that regulate the trade in hazardous chemicals and wastes. Treaties and directives from Africa, European Union, and South Pacific are discussed, including the Bamako Convention;

Waste Shipment Regulation (EC) Nº 1013/2006; Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS) Directive, 2011; Waste from Electrical and Electronic Equipment (WEEE) Directive, 2012; Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Regulation, 2006, and the Waigani Convention, 1995. Generally, this chapter builds on the principles and standards of e-waste management that have been discussed in Chapter 3 of this research. In Chapter 3, principles such as environmentally sound management (ESM) of wastes, prevention, precautionary, prior notification, and proximity principles were discussed. Under this Chapter, more emphasis is added to these principles based on the discussed conventional obligation.

Chapter 6: Status of E-Waste Laws, Enforcement, and Management within the GCC

This chapter discusses the domestication status of the international Conventions and principles by the GCC countries (i.e., Bahrain, Kuwait, Oman, Saudi Arabia, Qatar, and UAE). The conventions discussed among the respective countries are the Basel Convention 1989, Stockholm Convention 2001, Minamata Convention 2013, Rotterdam Convention 1998, and Montreal Protocol 1987. Further, this chapter discusses the environmental laws, decrees, regulations, and unified codes for the Gulf Cooperation Council. Most of the GCC Supreme Council laws are in the form of guidelines for the GCC member states and contain general provisions on environmental management. Finally, the national environmental laws, regulations, and mandates applicable to e-waste are discussed for every GCC country. The discussion of laws helps appreciate the legal framework for the management of e-waste at every state within the GCC.

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Chapter 7: Trends in E-Waste Production, Quantities, Flows, and Management Within the GCC Member States

The chapter analyzes the status of e-waste generation, quantities, and flows within the GCC. The Gulf Cooperation Council states including Qatar, Bahrain, Oman, Saudi Arabia, and the United Arab Emirates have recorded rapid population growth and economic development. The rise in population growth and economic development has been characterized by e-waste challenges that pose health and environmental sustainability risks among the GCC countries. The chapter further discusses the management of e-waste in the GCC countries.

Chapter 8: Findings, Analysis, and Discussions of the Legal Framework within the GCC

This chapter summarizes the findings of all the previous chapters, emphasizing their applicability in the GCC. The research objective was to establish whether the GCC has an adequate legal system to address the e-waste challenge and realize the economic benefit of e-wastes. Chapter 6 and 7 discussed the environmental laws and the trends on e-waste generation within the GCC member states. Although numerous laws touch on wastes generally, few of such laws regulate e-waste directly. As shall be seen in the first part of this chapter, most laws within the GCC member states only promulgate general principles. Besides, the GCC laws deal with maritime pollution more than hazardous wastes from waste electricals and electronic equipment. Therefore, the first part highlights the findings from the discussion of the GCC laws in Chapter 6. The second part of this chapter narrates the research findings on the compliance of GCC member states with the principles of environmental laws. These principles were highlighted in Chapter 3 of this research and form the basis of most legislations. The last part deals with the trends in the management of e-waste within the GCC that were highlighted in Chapter 7.

Chapter 9: Findings, Analysis, and Discussions on Recycling of E-wastes Within the GCC

This chapter summarizes the discussions in chapter 7 regarding the e-waste management initiatives within the different GCC states. The discussions in this chapter seek to elicit the analysis

on whether the production, processing, and recycling of e-waste within the GCC member states are proper. The discussions seek to establish whether recycling initiatives can support a circular economy where the recycled products from e-wastes are traded for economic gain.

Chapter 10: Conclusions and Recommendations

This chapter will summarize the discussions of chapters 2 to 9 and answer the research questions of the adequacy of the legal frameworks of the GCC member states. It will equally answer the question as to whether the waste practices within the GCC can support a circular economy and help the countries in minimizing pollution and maximizing the profits of recycled products. The chapter will wind up by giving recommendations on the areas that were researched and discussed.

Conclusion

The GCC countries, including Qatar, Bahrain, Saudi Arabia, United Arab Emirates, and Oman, continue to grapple with e-waste management to ensure a sustainable e-waste circular economy. Notably, e-waste generation in the GCC countries has increased in the recent past due to the growing population and industrial development. This chapter has laid the background of research on e-waste by describing the current status of e-waste generation and management in the GCC member states. One thing that emerges is that Saudi Arabia, with the largest population in the GCC, is the leading generator of e-waste in the region. Generally, all the GCC countries have established legal safeguards and programs for managing e-waste. However, limited legal frameworks, processes, and programs have been initiated in the GCC countries to manage e-wastes. This chapter discusses the research aims, which involve investigating whether the GCC states have an e-waste circular economy. The research also aims to identify the global best practices in e-waste to compare with the current practices of the GCC countries, such as the legal

framework for managing e-wastes, the environmental law principles, and the best technologies suitable for the e-waste circular economy. The research will be significant for various GCC country governments, researchers, policymakers, and organizations to identify the best e-waste management practices to achieve the e-waste circular economy.

The study uses a qualitative case study methodology following a descriptive study design to describe and compare the e-waste management practices in terms of technologies, policies, and legal frameworks among GCC member countries and the global best practices. The study methodology will effectively explore e-waste management in the GCC states to propose best practices to promote the e-waste circular economy. Finally, this chapter has provided an in-depth description of the thesis structure.

The next chapter will discuss the advanced technologies for recycling e-waste, including the separation of materials, thermal treatments, pyrometallurgical processes, and sensing technologies. The chapter offers an in-depth description of the European Recycling Platform that will act as a global best practice when exploring the e-waste management practices in the GCC. Finally, the chapter will describe the e-waste recycling procedures for individual WEEE materials, namely plastics, batteries, LCDs, rare earth metals, and refrigerators. The discussion will be critical in understanding the recycling processes for specific components of e-waste products to ensure an e-waste circular economy in the GCC.

CHAPTER TWO:RECYCLING TECHNOLOGIES FOR WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT

2.0 Introduction

Waste electronic and electronic equipment (WEEE) is a significant threat globally due to its toxic emissions affecting the biota. As a result, recycling of wastes is a critical topic in WEEE management, from waste treatment to the recovery of precious materials. However, not all recycling techniques will yield the maximum value of precious metals and plastics in electrical and electronic equipment waste. Similarly, not all recycling technologies are eco-friendly. This chapter focuses on the best available technology that yields the maximum content and remains environmentally friendly. Pyrometallurgical processes remain essential mechanisms for processing WEEE. The methods are used as the last steps of the recovery chain. Currently, Europe has about 10000 collectors, 1000 waste dismantling installations, and 100 pre-processing units.[26] The WEEE in the installations is primarily processed through smelting and incineration. Smelting is undertaken at high temperatures of about 1200 degrees Celsius.[27] The first section of this chapter deals with the environmentally unsound recycling procedures and technologies for recycling WEEE, focusing primarily on incineration because of its harmful impacts on the environment. The chapter discusses advanced technologies used in recycling WEEE, such as separation of materials, thermal treatments, pyrometallurgical processes, and sensing technologies. This chapter describes the basic principles of the European Recycling Platform (ERP). It ends with an in-depth discussion of the recycling procedures for individual materials in WEEE, such as plastics, batteries, LCDs, refrigerators, and rare earth metals.

[26] Gurgul, Agnieszka, Włodzimierz Szczepaniak, and Monika Zabłocka-Malicka. "Incineration, pyrolysis and gasification of electronic waste." In *E3S Web of conferences*, vol. 22, p. 00060. EDP Sciences, 2017. https://www.e3s-conferences.org/articles/e3sconf/pdf/2017/10/e3sconf_asee2017_00060.pdf

[27] Gurgul, Agnieszka, Włodzimierz Szczepaniak, and Monika Zabłocka-Malicka. "Incineration, pyrolysis and gasification of electronic waste." In *E3S Web of conferences*, vol. 22, p. 00060. EDP Sciences, 2017.

2.1 ENVIRONMENTALLY UNSOUND RECYCLING PROCEDURES AND TECHNOLOGIES

E-waste generally contains precious metals and components with high economic value when recycled. The concentration of such metals differs based on the type of e-waste, as demonstrated in Figure 2.1. below. However, the primary question of this research is how best a country can maximize the economic value of e-waste through recycling while minimizing the environmental and human costs. As will be discussed in Chapters 3, 4, and 5, a proper e-waste management regime strikes a balance between the economic value of e-waste and the impact of such wastes on the environment and human health. Essentially, all the laws, processes, and techniques aim at achieving different principles of environmentally sound management of e-waste. Most of these principles are discussed in Chapter 3, including the prevention principle. The prevention principle necessitates states to apply the best available technologies in recycling that minimize pollution to the environment and human beings.

Figure 2.1: The concentration of metals in WEEE scraps

Electronic waste	wt.%					ppm (wt.)		
	Fe	Cu	Al	Pb	Ni	Ag	Au	Pd
TV board	28	10	10	1.0	0.3	280	20	10
PC board	7	20	5	1.5	1	1000	250	110
Mobile phone	5	13	1	0.3	0.1	1380	350	210
Portable audio	23	21	1	0.14	0.03	150	10	4
DVD player	62	5	2	0.3	0.05	115	15	4
Calculator	4	3	5	0.1	0.5	260	50	5
Printed circuit boards	12	10	7	1.2	0.85	280	110	-

Source: Gurgul et al.[28]

Thus, it is imperative to note that realizing the economic value of e-waste entails proper recycling techniques that reduce pollution. Any technique that leads to pollution would therefore be categorized as environmentally unsound. Although such techniques may still be used in the

[28] Gurgul, Agnieszka, Włodzimierz Szczepaniak, and Monika Zabłocka-Malicka. "Incineration, pyrolysis and gasification of electronic waste." In *E3S Web of conferences*, vol. 22, p. 00060. EDP Sciences, 2017. https://www.e3s-conferences.org/articles/e3sconf/pdf/2017/10/e3sconf_asee2017_00060.pdf

informal and formal recycling models, they often lead to heavy pollution and increase the cost of recycling, especially in the formal recycling industries. Such unsound procedures in recycling e-waste materials include incineration or open burning.

2.1.1 Incineration of Waste Electrical and Electronic Wastes

Incineration is an energy-producing process that uses thermal decomposition at extreme temperatures to destroy and reduce the volume of wastes. Most municipal wastes end up in incinerators where they are burned as a way of managing them. These wastes include used electronics that are discarded alongside other household wastes.[29] However, some electronics are also dumped in landfills and open garbage disposal sites where informal recyclers pick them up.[30] Such wastes are usually subjected to open burning to recover precious metals and other components. However, incineration used for managing WEEE is often an unsound procedure for recycling wastes due to the generation of toxic substances.[31] Some incinerators, particularly the older plants, have limited pollution control mechanisms that make them more harmful to the environment.[32]

Further, incineration produces smoke during the combustion process. The smoke contains toxic substances like acid gases, particulates, heavy metals, carcinogen dioxin, and nitrogen oxide, harmful to the environment. For instance, dioxin resulting from the incineration process is considered a cancer-forming chemical that poses significant health risks to humans.[33] Notably,

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[29] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017). https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

[30] Olakitan Ogungbuyi, Innocent Chidi Nnorom, Oladele Osibanjo & Mathias Schluep.: E-waste country assessment Nigeria (Secretariat of the Basel Convention, 2012). http://www.basel.int/Portals/4/Basel%20Convention/docs/eWaste/EwasteAfrica_Nigeria-Assessment.pdf

[31] Holmes, Ian. "Dumping, burning and landfill." In *Electronic Waste Management*, pp. 75-90. Royal Society of Chemistry, 2008.

[32] Goodship, Vannessa, Ab Stevels, and Jaco Huisman, eds. *Waste electri;2cal and electronic equipment (WEEE) handbook*. Woodhead Publishing, 2019.

[33] Asante, Kwadwo Ansong, Sam Adu-Kumi, Kenta Nakahiro, Shin Takahashi, Tomohiko Isobe, Agus Sudaryanto, Gnanasekaran Devanathan et al. "Human exposure to PCBs, PBDEs and HBCDs in Ghana: Temporal variation,

communities where incineration is often undertaken experience long-term effects due to health hazards like cancer, congenital disabilities, neurological challenges, and reproductive dysfunctions because of their exposure to toxic metals and pollutants from the incineration plants.[34] Open burning and municipal incinerators are thus the most common forms of incineration, especially in the developing world. Incineration in the developed world encompasses pyrolysis, where substances are heated without oxygen into fumes, oils, and charcoal.[35] Incineration is critical when processing WEEE with a high concentration of valuable metals for advanced processing through hydrometallurgical means.

In some cases, incineration is done for combustible wastes or those with high amounts of organic contents.[36] One of the most common materials often incinerated by informal recyclers is the printed circuit boards (PCB).[37] These circuit boards form part of almost every piece of electrical and electronic equipment. They support the equipment and also serve as connection pathways where copper traces are used. It is estimated that printed circuit boards form up to 3% of the total weight of waste electrical and electronic equipment.[38] Since PCBs contain many

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sources of exposure and estimation of daily intakes by infants." *Environment international* 37, no. 5 (2011): 921-928. Available at: https://www.resource-recovery.net/sites/default/files/human_exposure_to_pcbs_pbdes_and_hbcds_in_ghana.pdf

[34] Otsuka, Masanari, Takaaki Itai, Kwadwo Ansong Asante, Mamoru Muto, and Shinsuke Tanabe. "Trace element contamination around the e-waste recycling site at Agbogbloshie, Accra City, Ghana." *Interdiscip Stud Environ Chem Environ Pollut Ecotoxicol* 6, no. 6 (2012): 161-167. Available at: https://www.terrapub.co.jp/onlineproceedings/ec/06/pdf/PR620.pdf

[35] Sivaramanan, Sivakumaran. "E-Waste Management, Disposal and Its Impacts on the Environment." *Universal Journal of Environmental Research & Technology* 3, no. 5 (2013). https://www.researchgate.net/publication/267217916_E-Waste_Management_Disposal_and_Its_Impacts_on_the_Environment

[36] Holmes, Ian. "Dumping, burning and landfill." In *Electronic Waste Management*, pp. 75-90. Royal Society of Chemistry, 2008.

[37] Alejandra Sepúlveda, Mathias Schluep, Fabrice G Renaud, Martin Streicher, Ruediger Kuehr, Christian Hagelüken, Andreas C Gerecke (2010) "A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipments during recycling: Examples from China and India." *Environmental Impact Assessment Review* 30: 1. 28–41. Available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.611.3030&rep=rep1&type=pdf

[38] Goodship, Vannessa, Ab Stevels, and Jaco Huisman, eds. *Waste electri;2cal and electronic equipment (WEEE) handbook*. Woodhead Publishing, 2019.

components, including hazardous materials and metals, the first used method to separate the metals from the rest of waste printed circuit boards is usually incineration.[39] However, incineration causes much harm to the environment and human health. As a result, other modern technologies, including pyrometallurgy and pyrolysis, are preferred.[40]

Other solid wastes, including waste electrical and electronic equipment that potentially harm the environment, can also be incinerated. The process includes burning cables and wires to recover copper.[41] Due to the environmental pollution that direct incineration may cause, various technologies have been developed to handle different physical forms and hazardous waste materials.[42] The notable subsystems in solid waste incineration include waste preparation and feeding, residual handling systems, combustion chamber, and air pollution control.[43]

Countries like Germany and Netherlands classify incineration residue as hazardous wastes because of the presence of toxic dioxins. China has banned the use of open burning to recover metals from e-waste, including PCBs.[44] Similarly, the US refers to incineration residue as hazardous ash whose disposal can only be undertaken in carefully designed landfills with leachate

[39] Song, Q., Li, J., 2014. "Environmental effects of heavy metals derived from the e-waste recycling activities in China: a systematic review." *Waste Management* 34 (12), 2587e2594.
[40] Awasthi, A.K., Zeng, X., Li, J., 2016c. Integrated bioleaching of copper metal from waste printed circuit board a comprehensive review of approaches and challenges. Environmental Science and Pollution Research 23, 21141e21156.
[41] Alejandra Sepúlveda, Mathias Schluep, Fabrice G Renaud, Martin Streicher, Ruediger Kuehr, Christian Hagelüken, Andreas C Gerecke (2010) "A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipments during recycling: Examples from China and India." *Environmental Impact Assessment Review* 30: 1. 28–41. Available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.611.3030&rep=rep1&type=pdf
[42] Goodship, Vannessa, Ab Stevels, and Jaco Huisman, eds. *Waste electri;2cal and electronic equipment (WEEE) handbook*. Woodhead Publishing, 2019.
[43]Farooqi, Zia Ur Rahman, Abdul Kareem, Faizan Rafi, and Shujahat Ali. "Solid Waste, Treatment Technologies, and Environmental Sustainability: Solid Wastes and Their Sustainable Management Practices." In *Handbook of Research on Waste Diversion and Minimization Technologies for the Industrial Sector*, pp. 35-57. IGI Global, 2021. https://www.researchgate.net/publication/344519543_Solid_Waste_Treatment_Technologies_and_Environmental_Sustainability
[44] Song, Q., Li, J., 2014. Environmental effects of heavy metals derived from the e-waste recycling activities in China: a systematic review. Waste Management 34 (12), 2587e2594.

collection mechanisms and standardized monitoring systems.[45] Besides, incinerators' bottom ash is only disposed to specified landfills and is separated from biodegradable waste materials to avoid mobilizing heavy metals and other toxic substances.[46] However, careful treatment of the residues can effectively transform the hazardous ash into valuable products, thus reducing landfill hazards. Some of the waste treatment mechanisms include stabilization, solidification and vitrification, and 3R processes.[47]

2.2 ADVANCED MODERN TECHNOLOGY OF RECYCLING E-WASTE

Modern technology is necessary to recycle wastes if states are to realize the economic value of wastes. As already seen, poor recycling technology can be very costly for both the environment and humans. Additionally, wrong dismantling and recovery of e-waste can lose other precious components of the wastes, such as gold. For instance, only 70% of gold traces may be recovered when e-wastes are dismantled manually from motherboards and contacts, as the rest are lost to dust and ferrous fractions. On the other hand, using technology can yield up to 80% of gold from the same motherboards and contacts.[48] Therefore, in recycling e-waste, the proper technology should ensure that all components of the electronic devices are recycled to their maximum capacity while hazardous components are also detoxified.[49] The recycling process often involves four processes of collection, dismantling, pre-processing, and end processing.[50] Hence, advanced

[45] Petts, J. "Incineration as a waste management option." *Waste incineration and the environment* (1994): 1-25.
[46] Petts, J. "Incineration as a waste management option." *Waste incineration and the environment* (1994): 1-25.
[47] Goodship, Vannessa, Ab Stevels, and Jaco Huisman, eds. *Waste electri;2cal and electronic equipment (WEEE) handbook*. Woodhead Publishing, 2019.
[48] Feng Wang, Jaco Huisman, Christina E M Meskers, Mathias Schluep, Ab Stevels, Christian Hagelüken (2012) "The Best-of-2-World's philosophy: Developing local dismantling and global infrastructure network for sustainable e-waste treatment in emerging economies." *Waste Management* 32: 2134–2146. Available at: http://publicationslist.org/data/mathias.schluep/ref-10/Wang_2012_Bo2W.pdf
[49] Feng Wang, Jaco Huisman, Christina E M Meskers, Mathias Schluep, Ab Stevels, Christian Hagelüken (2012) "The Best-of-2-World's philosophy: Developing local dismantling and global infrastructure network for sustainable e-waste treatment in emerging economies." *Waste Management* 32: 2134–2146. Available at: http://publicationslist.org/data/mathias.schluep/ref-10/Wang_2012_Bo2W.pdf
[50] Ibid.

technologies have focused on separating materials before they can be recycled using different methods.

Some of the best available technologies in recycling e-wastes are shown in the figure below. The analysis considers the technology that has been applied at each recycling stage and the recoverable materials involved at each stage. The figure equally highlights the economics of such pre-processing technologies. Realizing the economic value of the recycled material is an area of focus in this research; hence understanding the labor costs in modern recycling technologies is very important to this research.

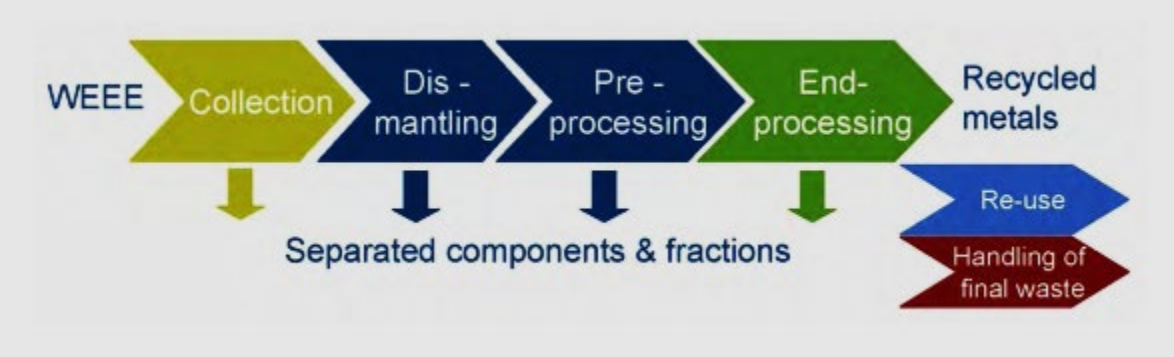
Figure 2.2.: Pre-Processing Technologies in the Recycling of E-Waste

	Waste streams	Economic attributes	Environmental attributes	Social attributes	Innovative technology*
Manual dismantling/ sorting of fractions	All	Low capital cost, sorting of valuable fractions/ components	Efficient sorting of fractions	Labour intensive, Job creation	Yes
De-gassing CFC, HCFC	Cooling and freezing	Mandatory requirement having low cost	Fundamental step to ensure control over hazardous substances having huge GWP potential	Job creation	Yes
Semi-automatic CRT cut and cleaning	CRT	Low capital and net cost	Low energy consumption	Labour intensive	Yes
Automatic shredding CRT	CRT	High capital cost	Higher energy consumption	Low job creation	No
Automatic Shredding and separation	All	High capital costs	Higher energy consumption	Low job creation	No, Feasible for specific activities
Automatic shredding and recovery CFC foam	Cooling and freezing	High capital costs	Higher energy consumption, Sealed container for titration	Low job creation	No

Source: *Solving the E-waste Problem (StEP)*, 2009[51]

Typically, recycling e-wastes starts with the collection, as shall be seen in the figure below. Additionally, more information about the collection and the different channels employed by states is discussed in Chapter 4 of this research. After collection, the materials are dismantled either mechanically or with the use of technology. This stage may be merged with the pre-processing phase, where incineration may be used as already discussed above. In an advanced technology model, hazardous substances contained in e-wastes should be removed at the pre-processing stage. This early separation helps protect the workers from exposure to hazardous substances and protect the environment.[52]

Figure 2.3.: Recycling Chain



Source: *Solving the E-waste Problem (StEP)*, 2009[53]

After the hazardous components are removed, they may be stored separately or treated in an environmentally sound manner. Capacitors, printed circuit boards (PCB), and batteries may be

[51] Schluep, Mathias, Christian Hagelueken, Ruediger Kuehr, Federico Magalini, Claudia Maurer, Christina Meskers, Esther Mueller, and Feng Wang. 2009. Recycling - from E-waste to Resources, Sustainable Innovation and Technology Transfer Industrial Sector *Studies*. Paris, France: United Nations Environment Programme (UNEP). Available at: https://www.researchgate.net/publication/278849195_Recycling_-_from_e-waste_to_resources

[52] Salhofer, S., Tesar, M., 2011. Assessment of removal of components containing hazardous substances from small WEEE in Austria. Journal of Hazardous Materials 186, 1481–1488. Available at: https://www.academia.edu/28067786/Assessment_of_removal_of_components_containing_hazardous_substances_from_small_WEEE_in_Austria

[53] Schluep, Mathias, Christian Hagelueken, Ruediger Kuehr, Federico Magalini, Claudia Maurer, Christina Meskers, Esther Mueller, and Feng Wang. 2009. Recycling - from E-waste to Resources, Sustainable Innovation and Technology Transfer Industrial Sector *Studies*. Paris, France: United Nations Environment Programme (UNEP). Available at: https://www.researchgate.net/publication/278849195_Recycling_-_from_e-waste_to_resources

separated, pre-processed, and channeled to different facilities to recover copper, nickel, and cobalt. Plastics may equally be separated from metals and processed separately. For refrigerants and cooling appliances, pre-processing involves de-gassing chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC).[54] As will be seen in Chapter 5, the CFCs and HCFCs are persistent organic substances that lead to depletion of the ozone layer and are subject to regulation. Most modern appliances have a reduced concentration of these substances, although the old cooling appliances still contain high levels. The best available technology must thus be employed to avoid air emission of CFC and HCFC from old appliances.

The last stage in e-waste recycling is the end processing phase which combines different technologies. Again, the quality of the end product and its economic value depends on the technology used. The best available technologies for end- processing include chemical, thermal, and metallurgical processes employed separately or combined to upgrade e-waste components and remove any traces of hazardous substances.[55] Best technologies have diverse treatment methods and lead to high rates of recovery, low pollution, and minimal labor costs, making them the most preferred. However, such technologies are costly and require very high investment capital.[56] Some of these modern technologies and processes will be discussed below.

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[54] Scottish Environmental Protection Agency. *Guidance on the Recovery and Disposal of Controlled Substances Contained in Refrigerators and Freezers*. Bristol, 2002. Available at: https://www.sepa.org.uk/media/155012/guidance_-recovery_storage_controlled-substances_in_fridge_freezers.pdf

[55] [55] Feng Wang, Jaco Huisman, Christina E M Meskers, Mathias Schluep, Ab Stevels, Christian Hagelüken (2012) "The Best-of-2-World's philosophy: Developing local dismantling and global infrastructure network for sustainable e-waste treatment in emerging economies." *Waste Management* 32: 2134–2146. Available at: http://publicationslist.org/data/mathias.schluep/ref-10/Wang_2012_Bo2W.pdf

[56] Schluep, Mathias, Christian Hagelueken, Ruediger Kuehr, Federico Magalini, Claudia Maurer, Christina Meskers, Esther Mueller, and Feng Wang. 2009. Recycling - from E-waste to Resources, Sustainable Innovation and Technology Transfer Industrial Sector *Studies*. Paris, France: United Nations Environment Programme (UNEP). Available at: https://www.researchgate.net/publication/278849195_Recycling_-_from_e-waste_to_resources

2.2.1 Use of Technology in Separation of Materials

Effective recycling requires robust separation to eliminate the reliance on the costly dismantling of wastes. The WEEE separation technologies arise from adapting existing techniques and novel methods for use in specified input streams. Further, more efficient routes are being developed for handling various input items. Notably, the current technologies can efficiently segregate plastics from other e-waste materials. However, the separation of multiple materials remains the primary aim of technologies like sensors that play a vital role in separation. The mechanical devices utilized for separating plastic materials comprise the air force sorter and weak flow watercourse separator.

Other adherent technologies have been applied in the US to gasify plastics in thermal screw feeds to ensure complete conversion processes to reform plastic wastes into secondary materials. The metals produced during separation can be recovered via techniques like leading, electro-wining, and electro-refining. There is a continuous search for new technologies to segregate and process various electronic wastes without losing the valuable components in an environmentally friendly manner. Some technologies adopted to separate materials and recover valuable metals include pyrometallurgy, hydrometallurgy, and electrochemistry.[57] The prevalent initial step for separating e-waste is mechanical processing to reduce the size and bulk and segregate the material fractions.[58] During mechanical processing, some unit operations encompass disassembling, crushing, air classification, vibrating screening, high tension segregation, and magnetic separation.

Electrostatic separators are being adopted to extract plastics, particularly those with small particle sizes. Sand-based fluidized beds are also being researched to facilitate gravity separation.

[57] Sahu, K. K., and A. Agrawal. "Processing of Electronic Waste (E-Waste)." (2008): 117-126.
[58] Schluep, Mathias, Christian Hagelueken, Ruediger Kuehr, Federico Magalini, Claudia Maurer, Christina Meskers, Esther Mueller, and Feng Wang. 2009. Recycling - from E-waste to Resources, Sustainable Innovation and Technology Transfer Industrial Sector *Studies*. Paris, France: United Nations Environment Programme (UNEP). Available at: https://www.researchgate.net/publication/278849195_Recycling_-_from_e-waste_to_resources

Additionally, magnetic separation and pyrolysis are significant technologies in the retrieval of carbon and dust. Notably, optoelectronic sorting is being developed to be used in separating materials during e-waste recycling.[59] Electromagnetic field techniques have been developed with pulsed excitation and combined permeability and conductivity of every material to enable their segregation at low fields. However, the metal pieces are removed from the conveyor belt at higher fields as signals are introduced to the processor to activate air nozzles that facilitate material separation in the falling area.

The magnetic separators include the low-density drum that is crucial in recovering ferromagnetic materials from non-ferrous metals.[60] The development of rare-earth alloy permanent magnets has enhanced the efficiency of magnetic separation methods by offering high field strengths and gradients.[61] Notably, magnetic separation tools for WEEE use ferrite and electromagnets to separate the ferrous magnetic materials. The density separation technology is also suitable for separating heavier materials from lighter ones.[62] The segmentation based on density is enabled by the gravity concentration, which effectively segregates materials of various gravity by their relative movement due to a force of gravity or resistance to motion resulting from air or water.[63] Using air for separating materials with different densities has been a common practice that can be directly applied to e-waste separation during recycling.

[59] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110.
[60] Xakalashe, Buhle S., Randburg Mintek, K. Seongjun, and J. Cui. "An overview of recycling of electronic waste PART 2." *Chemical Technology* (2012): 23-26.
[61] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110.
[62] Xakalashe, Buhle S., Randburg Mintek, K. Seongjun, and J. Cui. "An overview of recycling of electronic waste PART 2." *Chemical Technology* (2012): 23-26.
[63] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110.

Lastly, eddy current separation can be applied to separate non-ferrous materials. The technology is used when substances of non-ferrous materials pass through a rotating magnet at a higher speed. In return, eddy currents are created around the non-ferrous metal, thus creating a magnetic field.[64] As the polarity of the magnetic field equals the rotating magnet, there is the repelling of the non-ferrous materials from the magnet, thus enabling the separation of the metals.

2.2.2 Use of Thermal Treatments

Thermal treatment technologies utilize methods like pyrolysis and gasification to recycle wastes.[65] The thermal treatment method can enhance the recovery and efficiency of valuable metals before leaching. The WEEE components like the small capacitors, IC chips, and connectors are passed through chemical solutions to generate a high leaching rate to recover valuable metals.[66] Thermal treatment is used during the hydrometallurgical leaching process to increase the recovery rate of the precious metals. Notably, the thermal treatment of e-wastes that follows the hydrometallurgical process offers the most favorable outcomes among the eco-friendly techniques that facilitate the recovery of metals and proper treatment of toxic compounds.

Besides, thermal treatment is preferred in e-waste recycling because it effectively reduces the bulk of e-waste materials and avoids harmful liquid effluent from the primary cylinder. However, further refining is needed after thermal treatments to extract pure metals valuable for other uses. It is important to note that thermal treatments have not been widely used to recycle whole appliances. However, more research has been ongoing, often borrowing concepts from mining procedures and techniques to implement thermal treatment in e-waste treatment.[67] After

[64] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110.
[65] Defra. "Advanced Thermal Treatment of Municipal Solid Waste." (2013). p.3
[66] Vermeșan, Horațiu, Ancuța-Elena Tiuc, and Marius Purcar. "Advanced recovery techniques for waste materials from IT and telecommunication equipment printed circuit boards." *Sustainability* 12, no. 1 (2020): 74. p.14.
[67] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110. P.105

the initial sorting of e-waste materials, the organic content is turned into ash used as the feedstock during the Pyrometallurgical processing. The residue from the process is often refined metal ingots comprising aluminum, copper-rich valuable metals, ferrous materials, and mixed compound of Pb/Sn.[68] Final products are taken through further refining. Other thermal routes during the thermal treatment are the encapsulation that uses glass or binder to generate low-grade block materials that can be utilized in construction. The harmful substances from the thermal treatment process are safely sealed to protect the environment.[69] Other areas that require further research are whether vacuum, thermal plasmas, and lasers can be applied to improve the thermal treatment of e-wastes.

2.2.3 Use of Pyrometallurgical Processes

The pyrometallurgical process is applied to recover valuable materials from e-waste products. Every product stream from the pyrometallurgical process, such as ferromanganese, high-grade titania, and micro silica, can be reused. Rotary kilns, electric arc furnaces, and blast furnaces are the most common equipment for pyrometallurgical processes. Notably, pyrometallurgy is a conventional technique used to recover non-ferrous metals and other precious metals from WEEE. The process involves smelting or melting e-waste and retrieving them from the furnace. Pyrometallurgy can be applied to facilitate copper recovery. For example, the e-waste with 5-40% Cu is directed into the blast furnace. Reducing agents like scrap iron and plastics are used to reduce copper compounds. Various impurities like lead and zinc go to the slag as copper is tapped and directed to the converters to blow off the air and produce blister copper. The blister copper is refined in the anode furnace and cast with a 99% purity level.

[68] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110. P.105

[69] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110. P.105

Using pyrometallurgical has various limitations. First, aluminium is often lost to the slag because it is a highly stable oxide, but it is not needed. Secondly, relying on traditional smelters to process ores is ineffective, while the new smelters are costly.[70] Finally, pyrometallurgy only allows for the partial separation of metals, thus requiring other advanced techniques like hydrometallurgy to complete the separation process.

2.2.4 Hydrometallurgical Extraction

The hydrometallurgical extraction technique is most suitable for extracting precious metals. Various processes relying on strong acids and hydrogen peroxide have been created for e-waste recycling. For example, fluoroboric acid is critical for extracting precious metals from mixed compounds such as products from the pyrolytic processes.[71] Notably, the hydrometallurgical recycling process is easier to control, predict and use at a high level of precision than the pyrometallurgical processes. The hydrometallurgical process begins with leaching, where metals are converted into soluble salts in an aqueous form. Leaching agents utilized during the process comprise thiourea, halides, thiosulfate, and cyanide.[72] The leaching is followed by refining through filtration or combustion to achieve high purity products.

2.2.5 Use of Sensing Technologies

Sensing techniques can enhance the effectiveness of WEEE recycling. The technologies facilitate the implementation of automated disassembly for improved separation. Notably, the optoelectronic users that apply traditional imaging tools can be used to segregate shape and color. Further, electromagnetic sensing allows the identification of metals and plastics selectively ejected

[70] Xakalashe, Buhle S., Randburg Mintek, K. Seongjun, and J. Cui. "An overview of recycling of electronic waste PART 2." *Chemical Technology* (2012): 23-26. https://www.researchgate.net/publication/306286287_An_overview_of_recycling_of_electronic_waste_-_Part_2

[71] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110.

[72] Xakalashe, Buhle S., Randburg Mintek, K. Seongjun, and J. Cui. "An overview of recycling of electronic waste PART 2." *Chemical Technology* (2012): 23-26.

during the automated separation processes. Laser-Induced Breakdown Spectroscopy has been adapted for separating metals since it detects brominated flame retardants. The technology has a high-speed level and precision which makes WEEE recycling economically viable. Notably, other lab analytical methodologies being studied include laser-induced fluorescence and X-rays.[73] Electromagnetic sensing is also being developed to enhance WEEE recycling.

2.2.6 Dry Capture Technologies

The dry capture technology is instrumental in extraction and filtration to separate valuable metals from the WEEE. The emergence of nanotechnology like ultrafiltration has advanced the dry capture technique. However, there are still limited dry capture technologies for WEEE recycling, but it remains an area of concern.[74] Most importantly, the fine powder generation that accounts for 4% of the WEEE materials creates an interest in dry capture technologies.

2.2.7 Biotechnological Capture

The application of microbial cells in WEEE recycling has attracted much attention. As a result, biotechnological capture is being developed to apply microbial cells to recover metals from leachate solutions generated from the WEEE.[75] Notably, most micro-organisms can capture metals in the environment. Further, using renewable biologically derived materials is being researched to improve WEEE recycling in the future. For example, chitosan, a structural component in the crustacean's exoskeletons, is being developed to enhance its selectivity to recover precious metals. Further, bacterial species like the Acidithiobacillus oxidize sulphur during the metal solubilization

[73] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110.
[74] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110.
[75] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110.

process for e-waste recycling.[76] Iron oxidizers like L. ferrooxidans and L. ferriphilum are used to oxidize iron during the e-waste recycling process.

2.2.8 Design for Recycling and Inverse Manufacturing

The disassembly method has proved to be a costly procedure during WEEE recycling. As a result, equipment design has been proposed as a suitable strategy for reducing the costs of disassembly by assuring efficient use of resources. Notably, institutions such as Environwise, SUMEEPnet, and Sustainable Design Network have developed critical design principles.[77] The equipment design can be augmented by inverse manufacturing that adequately supports the reverse supply chain infrastructure. Significant developments in equipment design include the shape memory metals and polymers that can return to their original shapes after heating, thus helping during disassembly. Further, components generated from the materials can be carefully designed to release upon heating, as demonstrated on LCD screens.

2.3 EUROPEAN RECYCLING PLATFORM (ERP)

2.3.1 Basic Principles of ERP

The European Recycling Platform (ERP) was founded on six basic principles outlining the collection and take-back provisions, financing historical waste, data, mandatory registration, individual producer responsibility, and competition in compliance systems. In Europe, many countries enacted a law that holds producers liable for the collection and environmentally friendly treatment of end-use products. Manufacturers manufacture brand names according to the legislation, and a stylized model is used to determine to take back and no take-back guidelines,

[76] Awasthi, Abhishek Kumar, Mohammed Hasan, Yogendra Kumar Mishra, Akhilesh Kumar Pandey, Bhupendra Nath Tiwary, Ramesh C. Kuhad, Vijai Kumar Gupta, and Vijay Kumar Thakur. "Environmentally sound system for E-waste: Biotechnological perspectives." *Current Research in Biotechnology* 1 (2019): 58-64.
[77] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110. P.120

collection, and reuse targets.[78] On historical financing waste, whereas the ERP requires producers to communicate their waste management costs to the markets, the legislation must not mandate uniform fixed charges or transfer charges to a central system.

The primary guideline on competition in compliance systems requires all European member states to implement competitive compliance mechanisms that allow producers to choose between producer compliance schemes and enhance competitive pressures in all critical aspects of the system.

The Individual Producer Responsibility guideline is a blueprint tool that offers inducements to all European manufacturers to take charge of the whole lifecycle of their goods, inclusive of the disposal stage.[79] The policy holds producers and importers of products liable for the environmental effects through the products' lifecycle. Manufacturers align to the guideline by designing goods to decrease the ecological life-process impact and welcome economic, physical and legal liability of environmental effects that cannot be removed.[80] The guideline on data requires National Registers in member states to determine tonnage (sales) information and determine materials data regularly. Member states are required to conduct a quarterly statistical assessment of materials and sales data by manufacturers. Similarly, the mandatory registration guidelines require all producers within Europe to seek registration in which the National Register issues them a unique serial number before making sales.[81]

[78] Esenduran, Gökçe, Eda Kemahlıoğlu-Ziya, and Jayashankar M. Swaminathan. "Take-back legislation: Consequences for remanufacturing and environment." *Decision Sciences* 47, no. 2 (2016): 219-256.
[79]Butler, S. C. O. T. T. *European Recycling Platform (ERP): A Pan-European Solution to WEEE Compliance*. RSC Publishing, Cambridge, UK, 2009
[80] Sander, Knut, Stephanie Schilling, Naoko Tojo, Chris van Rossem, Jan Vernon, and Carolyn George. "The producer responsibility principle of the WEEE Directive." *Final Report* 19 (2007): 2007.
[81]Butler, S. C. O. T. T. *European Recycling Platform (ERP): A Pan-European Solution to WEEE Compliance*. RSC Publishing, Cambridge, UK, 2009

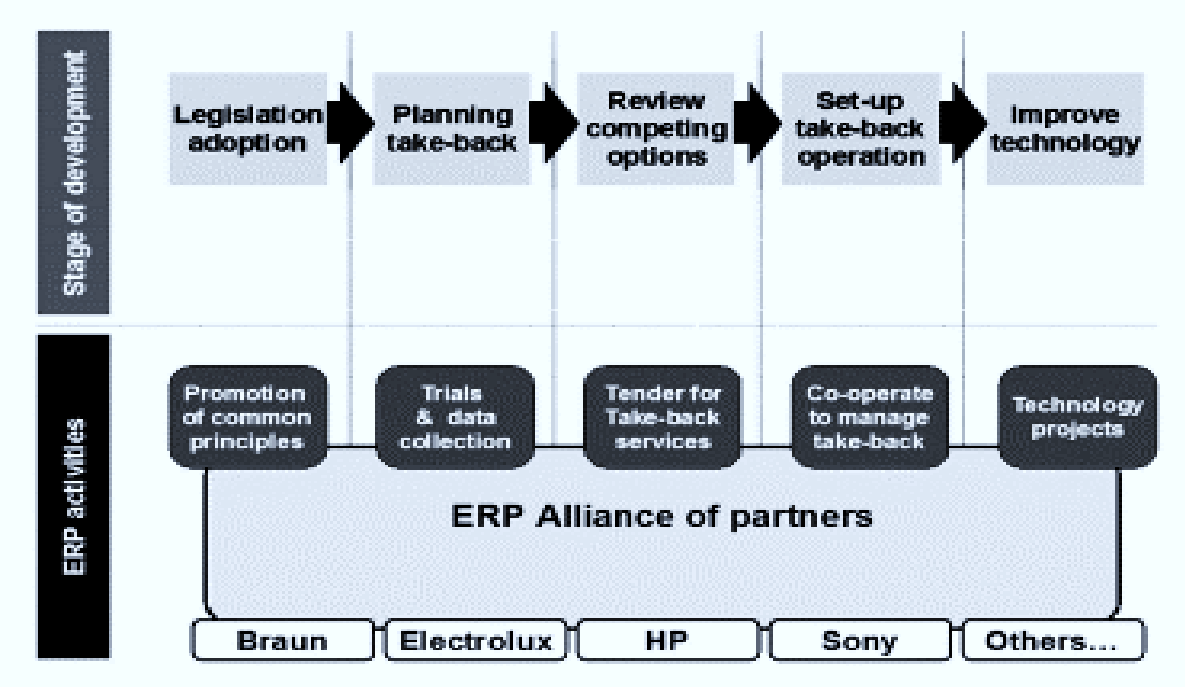
2.3.2 Structural Components of EPR

Established in 2002, the European Recycling Platform (EPR) created and operated a typical waste management structure comprising crucial components, including the overall goals, initial configuration, work plan, and current system. Since its establishment, the ERP was designed to meet the particular needs of electronic and electrical manufacturers. Moreover, it promotes innovative and cost-effective waste recycling approaches while embracing the fundamental concepts of individual manufacturer responsibility in line with the European Union directives. It also pioneers chances for pan-European reprocessing services and transborder rivalry in the waste control service markets.

When it was incepted, member state representatives were part of the steering committee that oversaw the national teams' control of ERP formation against the backdrop of federal execution of WEEE guidelines. Representatives from member states made up the sub-committees that oversaw communications, legal issues, and operations within the ERP. The founding members established and provided a work plan to allow the ERP to form, choose operational partners, and ultimately grow into a stand-alone organization.[82] The work plan focused on estimating annual WEEE volumes to be managed by ERP, determine potential service partners, determine realistic cost-saving practices, and completing final tender procedures, as shown in the figure below.

[82] Butler, S. C. O. T. T. *European Recycling Platform (ERP): A Pan-European Solution to WEEE Compliance*. RSC Publishing, Cambridge, UK, 2009

Figure 2.4: The ERP Work Plan (Butler)



Source: Butler. *European Recycling Platform (ERP).*[83]

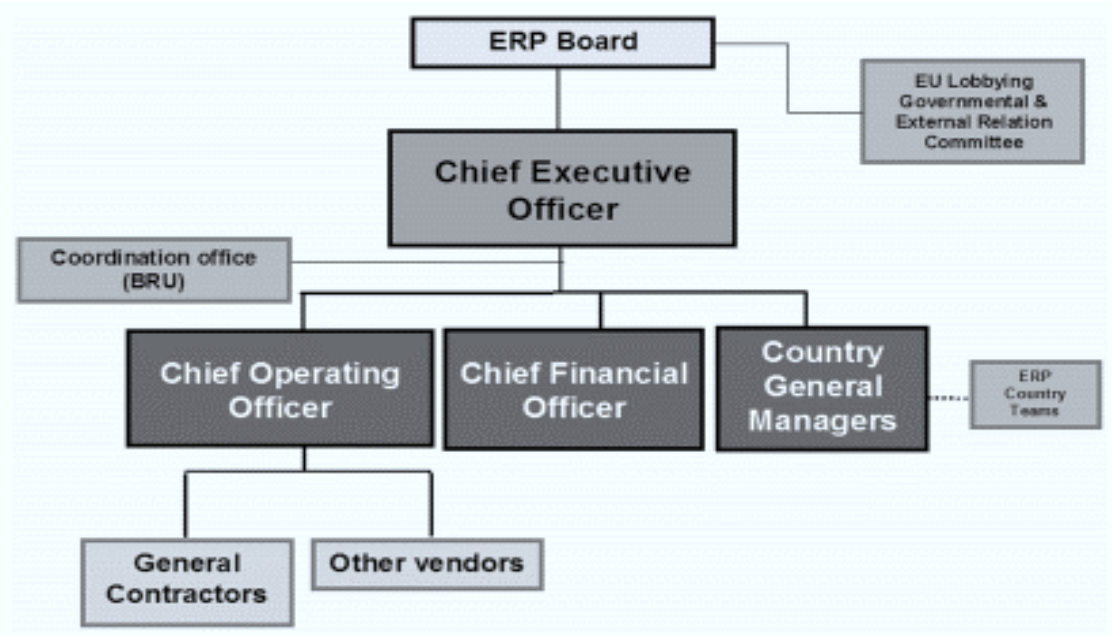
The organization has a relatively small workforce and implements a lean structure that outsources critical operations to general contractors to achieve competitiveness and operational flexibility. It employs self-financing mechanisms to promote high-quality environmental guidelines, cost-effectiveness, transparent costing techniques, and innovative recycling approaches.[84] With the transition from a start-up organization to complete operations, the ERP's board approved a new leadership structure. The board is the crucial decision-making function of the ERP tasked with lobbying, governance, and external relations. The chief executive officer is the senior-most member of the board and is assisted by the coordination office. The third tier of

[83] Butler, S. C. O. T. T. *European Recycling Platform (ERP): A Pan-European Solution to WEEE Compliance*. RSC Publishing, Cambridge, UK, 2009

[84] Lazzarin, Lorianna, and Sigrid Kusch. "E-Waste management framework and the importance of producer responsibility and proactive hackerspaces." *Proceedings EIIC* (2015): 188-192.

leadership includes the chief financial officer, operating officer, and the country general managers in charge of overseeing functions in member states (ERP country teams), general contractors, and other vendors within the structure.

Figure 2.5: The ERP Work Plan (Butler)



Source: Butler. *European Recycling Platform (ERP).*[85]

2.3.3 Scope of Recycling Services within the ERP

The ERP provides direct compliance in nine states, including Germany, Italy, Austria, Spain, France, Ireland, Poland, the UK, and Portugal. The organization is managed with a similar business focus to its members to develop their market leadership positions. It outsources all its critical services with a lean structure to achieve operational flexibility and reactivity to market opportunities to maintain its competitive advantage. The general contractors manage and operate all critical services on the take-back procedures and serve collection points to achieve compliance.

[85] Butler, S. C. O. T. T. *European Recycling Platform (ERP): A Pan-European Solution to WEEE Compliance*. RSC Publishing, Cambridge, UK, 2009

Collection, recycling, operations, and reporting services are overseen by two contractors chosen after strict tendering procedures. For example, Geodis Valenda provides contractual services in France, Italy, Ireland, Spain, Portugal, and the UK. Geodis Valenda is a French-based specializing in reverse logistics. In the other remaining countries of Poland, Austria, and Germany, Stena Metall is the general contractor and offers a wide range of environmental and recycling services.[86] ERP provides recycling services based on critical guidelines crucial in protecting business, the environment, and consumers. These functions are monitored regularly based on the volumes collected and treated, process audits, and key performance indicators.[87]

By agreeing with WEEE, ERP now allows its European members to go beyond the previous nine states by operating directly through its contractors by registering with the Euro PLUS Package. Under this package and through its general contractors, the ERP provides financial guarantees, reporting, business and legal consulting, advice on WEEE licensure, and connecting members to national recycling solutions outside Europe.[88] ERP's scope was enhanced through the ERP Directive and now covers all energy-associated goods. Usually, energy-connected products do not require energy during the use phase but impact energy utilization of other equipment. Examples include water-saving showerheads, windows, and insulating materials.[89]

The ERP recycles many materials, including huge domestic devices such as cookers, cleaning machines, tumble dryers, and dishwashers. The other category includes cooling appliances like freezers, ridges, and water coolers. Recently ERP undertook to recycle appliances

[86] Butler, S. C. O. T. T. *European Recycling Platform (ERP): A Pan-European Solution to WEEE Compliance*. RSC Publishing, Cambridge, UK, 2009
[87] Butler, S. C. O. T. T. *European Recycling Platform (ERP): A Pan-European Solution to WEEE Compliance*. RSC Publishing, Cambridge, UK, 2009
[88] Butler, S. C. O. T. T. *European Recycling Platform (ERP): A Pan-European Solution to WEEE Compliance*. RSC Publishing, Cambridge, UK, 2009.
[89] Nissen, Nils F. "ErP–the European directive on ecodesign." In *Waste electrical and electronic equipment (WEEE) handbook*. Woodhead Publishing, 2019. pp. 423-44.

containing refrigerant gases usually categorized as ozone-depleting substances. Moreover, the organization recycles display equipment like computer monitors, flat-screen TVs, and cathode-ray tubes in old TV sets.[90] Cathode ray tubes contain dangerous leaded glass, race metals, phosphor powder, and copper to be reused to manufacture new products. ERP also deals with small appliances, including but not limited to sewing machines, vacuum cleaners, toasters, and coffee machines. The reuse procedure includes manual pre-treatment, compressing, picking station, mincing, and separation. For gas discharge lamps, the process consists of shredding, dust recovery, and alienation. ERP also reuses packaging materials (plastics, cardboards, and glass), batteries with toxic heavy metals like mercury, cadmium, nickel, and photovoltaic panels.[91]

2.3.4 Producer Responsibility Schemes, Compliance, and Implementation

The WEEE Directive fosters and supports the Producer Responsibility guideline seeking to make the manufacturers, retailers, importers, and distributors liable for taking charge of a product that becomes obsolete. It means that manufacturers are assigned managerial and financial responsibility for the recycling and recovery of their products. Producer Responsibility was coined from the concept of the Extended Producer Responsibility in the 1990s as a market-oriented approach in Sweden.[92]It was soon perceived to be an effective strategy for environmental protection policies, and it was employed by ERP and organizations like the Organization for Economic Co-operation and Development (OECD).[93]

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[90] European Recycling Platform (ERP). "What happens to your waste • ERP global." ERP Global. Last modified July 28, 2017. https://erp-recycling.org/learning-centre/what-happens-to-your-waste/.
[91] European Recycling Platform (ERP). "What happens to your waste • ERP global." ERP Global. Last modified July 28, 2017. https://erp-recycling.org/learning-centre/what-happens-to-your-waste/.
[92] Calliafas, Peter, Margaret P. Bates, Gary Griffiths, Adrian Harding, Adrian Hawkes, Leigh Holloway, Lucy Keal, et al. "Waste Electrical and Electronic Equipment (WEEE) regulations: individual producer responsibility (IPR) in a UK context." (2012).
[93] Lazzarin, Lorianna, and Sigrid Kusch. "E-Waste management framework and the importance of producer responsibility and proactive hackerspaces." *Proceedings EIIC* (2015): 188-192.

Making electrical and electronic manufacturers responsible for taking the financial responsibility of their branded products' end-life costs is the critical objective of ERP. The ERP advises members on vital modifications in product design that manufacturers can undertake to impact product disposal costs directly. In the absence of Producer Responsibility Schemes, the stimulus for design enhancements is lost. The European WEEE directives (Article 8.2) require individual producer responsibility for all products put on the market before specific dates. Implementation of article 8.2 provisions sometimes presents challenges to ERP. For example, member states including Spain, Denmark, Finland, Greece, Slovenia, Bulgaria, France, Latvia, and Portugal omitted the requirements of this article by including the WEEE Directive in their national laws. With such strategies in place, the laws in these states make manufacturers jointly responsible for future product recycling, making it challenging to execute individual producer responsibility guidelines.

The treaty obliges individual member states to implement the WEEE Directive in full effect in both practice and legislation, adhere to the directive's wording, purpose, and objectives, and not create national laws that inhibit attaining the directive's goals. It is legally binding to all members to ensure that the individual producer responsibility guideline is correctly implemented and transposed within its national legislation. ERP extends the producer's liability to the recovery, collection, and later disposal phases to achieve a lifecycle perspective. The responsibility requires producers to develop more innovative designs of durable products and encourages manufacturers to lower the waste costs by providing cheap and easily recyclable products.[94]

[94] Lazzarin, Lorianna, and Sigrid Kusch. "E-Waste management framework and the importance of producer responsibility and proactive hackerspaces." *Proceedings EIIC* (2015): 188-192.

2.3.5 Proper Identification/ Marking of Electrical and Electronic Equipment

The ERP sets the EU guidelines, procedures, and rules regarding collecting, storage, sorting, treatment, refining, transportation, and discarding all types of waste electrical and electronic equipment to offer conformity identification and verification.[95]Most electronic and electrical products produced and sold in the European Union need a particular marking with a few exceptions. WEEE marking is compulsory for all ERP members for the following products for easy identification. Extensive equipment with an external dimension exceeding 50cm, including rooftop solar panels, washing machines, copy machines, and those below 50cm like smoke detectors, watches, and vacuum cleaners. Small telecommunications and IT equipment and temperature exchange products like air conditioning units and fridges. Others include lamps, monitors, screens, and equipment containing screens.[96]

In the EU, the WEEE requires all electronic and electric devices to bear identification marks like the trademark or a brand name. The products are also supposed to take the symbol of a crossed-out wheeled bin. The goods are also supposed to contain the date upon which they were placed in the market. The labels need to be printed on the products and should be readable, visible, and permanent. In some scenarios, the inscriptions can be inscribed on the cover, warranty leaflet, or directions if the product is too small or, in cases, the descriptions impact the function. The labels indicate that the goods should not be discarded unsorted but be sent to separate collection facilities for recycling and recovery. Reporting and registration to the national register are free, but there are financial responsibilities associated with waste management. Apart from registering and fixing the WEEE symbols, ERP recommends end of life phase of electronic and electric goods.

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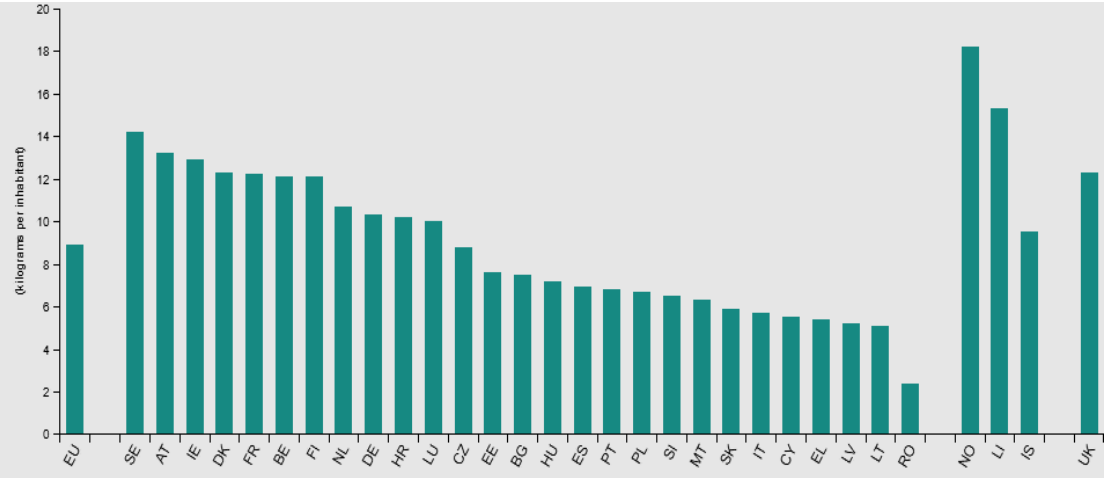
[95] Herreras-Martínez, L., and P. Leroy. "The WEEE forum and the WEEE label of excellence project." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 185-205. Woodhead Publishing, 2019.
[96] European Union. "WEEE - What Does the Label Mean, EU Requirements." Your Europe. Last modified November 12, 2020. https://europa.eu/youreurope/business/product-requirements/labels-markings/weee-label/index_en.htm.

2.3.6 Collection of Waste Electrical and Electronic Equipment

The main goal of the WEEE Directive is to advance the collection, reuse, recovery, and reprocessing of electrical and electronic products. In 2018, the collection rate of electronic and electrical waste was 47% in Europe, ceased by the magnitude of electronic and electrical waste collected in association with customers' intermediate goods in the three previous years.[97]

Figure 2.6: Waste electrical and electronic equipment collected in 2018



Source: European Commission.[98]

Even though collection mechanisms vary across the ERP member states, the standard collection centers for WEEE typically include electric retailers, civic amenity centers and EEE producer operated by own take-back systems. The collection centers generally are served by producer compliance schemes. Product categories applying to EEE include automatic dispensers, household appliances, medical equipment, telecommunication, IT tools, monitoring and control,

[97] European Commission. "Waste Statistics - Electrical and Electronic Equipment - Statistics Explained." European Commission. Last modified June 24, 2021. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_electrical_and_electronic_equipment&oldid=398212.
[98] European Commission. "Waste Statistics - Electrical and Electronic Equipment - Statistics Explained." European Commission. Last modified June 24, 2021. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_electrical_and_electronic_equipment&oldid=398212.

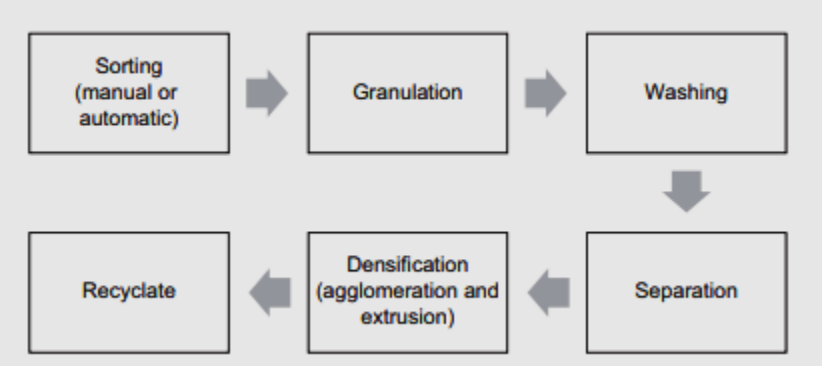
lighting, sports, leisure, toys, and other consumer products.[99] In member states, producer compliance schemes coordinate the legal compliance of EEE manufacturing members. Although their roles and responsibilities differ, the projects are meant to register producing members with licensure bodies, collect sales information from member states and report to the enforcing agencies.

Moreover, the producer compliance schemes also create partnerships with civic amenity sites and retailers to obtain access to WEEE, confirm compliance of members to enforcement agencies, and manage service partnerships to collect and treat wastes in line with the WEEE Directive obligations and member responsibilities. However, there exist differences between how members implement and interpret the WEEE Directive into their national legislation. Key areas presenting diverse views include definitions of WEE, registrations, application fees to carter for recycling costs, and WEEE weights.[100]

2.4 RECYCLING OF INDIVIDUAL MATERIALS IN WASTE ELECTRICAL AND ELECTRONIC WASTES

2.4.1 Recycling Plastics from Waste Electrical and Electronic Equipment

Figure 2.7: Mechanical recycling processes of polymers p.283



[99] European Commission. "Waste Statistics - Electrical and Electronic Equipment - Statistics Explained." European Commission. Last modified June 24, 2021. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_electrical_and_electronic_equipment&oldid=398212.

[100]Butler, S. C. O. T. T. *European Recycling Platform (ERP): A Pan-European Solution to WEEE Compliance*. RSC Publishing, Cambridge, UK, 2009.

Source: Butler. *European Recycling Platform (ERP).*[101]

The recycling of plastics or polymers from WEEE is primarily undertaken through mechanical processes. The recycling process begins with waste collection from domestic, industrial sources and centralized collection locations.[102] The WEEE are sorted and sizes reduced. Further separation is done to prepare them into usable material. The separation step is specifically designed to segregate polymers into various families based on their density, visual elements, spectra, and triboelectric. After separating polymers into their generic types, the density is increased to generate a usable pellet.

Manual separation and sorting of WEEE can be replaced by an automated method which is more commercially viable. The automatic separation relies on the physical elements of the wastes to identify their types and the relevant separation route. One advantage of the automated separation system is that it is cost-effective to operate. The size of WEEE is reduced using granulation where the material types are separated. Notably, the granulation process is premised on a rotary cutting system where rotary and stationary blades are fixed into the machine to enable rapid changeovers. Polymers are processed with fillers through the granulator while the screen allows the resulting waste to fall through gravity.[103] Further, the granulated WEEE is washed by passing it through a washing tank to eliminate any adhesive residues and dirt debris. Water and surfactants are utilized during the washing.

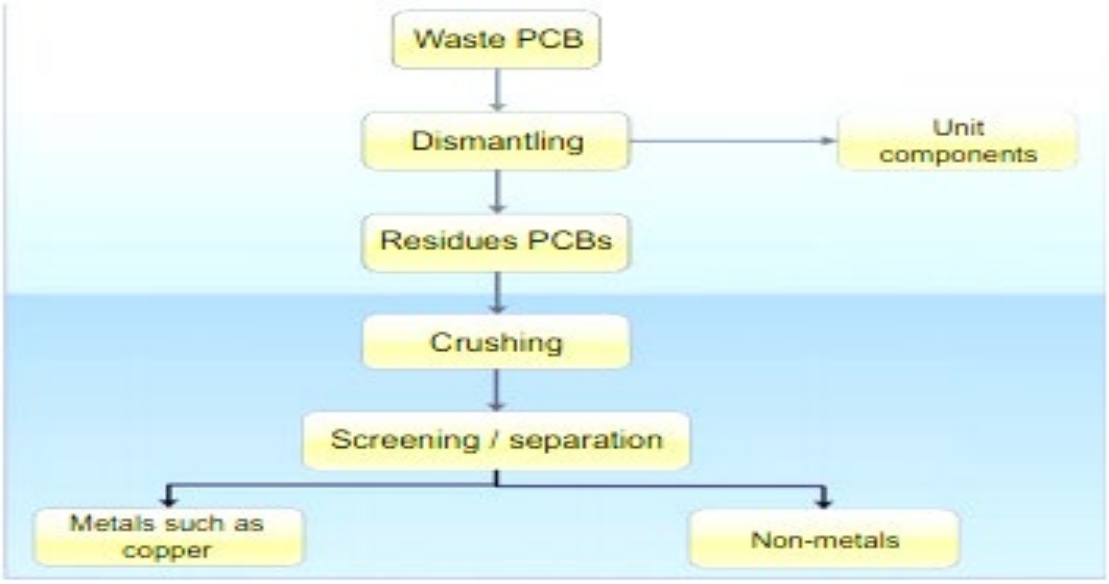
The polymer waste is sorted after washing using air table sorting, flotation sorting, and hydro-cyclone sorting. One unique sorting method is electrostatic sorting. The method applies the

[101] Butler, S. C. O. T. T. *European Recycling Platform (ERP): A Pan-European Solution to WEEE Compliance*. RSC Publishing, Cambridge, UK, 2009.
[102] Makenji, K., and M. Savage. "Mechanical methods of recycling plastics from WEEE." In *Waste electrical and electronic equipment (WEEE) handbook*, pp. 212-238. Woodhead Publishing, 2012.
[103] Makenji, K., and M. Savage. "Mechanical methods of recycling plastics from WEEE." In *Waste electrical and electronic equipment (WEEE) handbook*, pp. 212-238. Woodhead Publishing, 2012.

basics of triboelectric charging, where a free-fall separator depends on the electrical conductivity characteristics of the polymer materials.[104] Notably, materials are segregated as discrete particles with different electric conductive properties. The WEEE is converted into reusable material after collection, size reduction, cleaning, and sorting. The plastic material density will be added through the densification process to make it usable after recycling. Densification involves taking a low bulk density material and increasing its density to make it more usable and transportable. Various methods for densification include using pelletizers and compressing the polymer through a die, resulting in frictional heat that enables the joining together of polymers. As a result, the recycled polymer material is made for various uses.

2.4.2 Processes in Recycling Printed Circuit Boards

Figure 2: Mechanical process for recycling waste PCBs



Source: Makenji and Savage.[105]

[104] Makenji, K., and M. Savage. "Mechanical methods of recycling plastics from WEEE." In *Waste electrical and electronic equipment (WEEE) handbook*, pp. 212-238. Woodhead Publishing, 2012.
[105] Makenji, K., and M. Savage. "Mechanical methods of recycling plastics from WEEE." In *Waste electrical and electronic equipment (WEEE) handbook*, pp. 212-238. Woodhead Publishing, 2012.

The printed circuit boards are primarily utilized to connect electronic components through conductive tracks, pathways, and signal traces applied when manufacturing computers, machines, and electronic equipment. Recycling PCBs begins with dismantling the PCBs to obtain valuable materials like cables, cell batteries, and capacitors.[106] Automated disassembly can be adopted to foster the efficiency of the disassembly process. The dismantling of electronic components from the PCBs is crucial in reducing environmental pollution, and conversing resources since the valuable components are reused for other tasks. Disassembling is followed by size reduction and separation.

Mechanical techniques such as cutting, crushing, and grinding are applied to minimize the PCBs of various size particles. The separation of small materials is done by physical, magnetic, and electrostatic processes. Notably, the magnetic separation technique is undertaken using a stable magnet iron separator in a dry environment, followed by the eddy current technology in a wet climate.[107] Other methods used to separate metallic and non-metallic apply the electrostatic principles. The separation process occurs in a high electrostatic voltage to obtain a copper powder. Various technologies used to recover copper and other valuable metals from waste PCBs are Pyrometallurgy and hydrometallurgy, which are already discussed in section 2.2 above.

However, recycling PCBs poses severe risks to the environment. Waste air and industrial dust, including toxic gases like lead fume and dioxin, are released, thus threatening the population's health.[108] Further, the process consumes about 140 kW per hour, thus causing high impacts on the environment. The physical process of PCB recycling causes damage to human health. Therefore,

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[106] Awasthi, Abhishek Kumar, and Xianlai Zeng. "Recycling printed circuit boards." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 311-325. Woodhead Publishing, 2019.
[107] Awasthi, Abhishek Kumar, and Xianlai Zeng. "Recycling printed circuit boards." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 311-325. Woodhead Publishing, 2019.
[108] Xiang, Dong, Peng Mou, Jinsong Wang, Guanghong Duan, and Hong C. Zhang. "Printed circuit board recycling process and its environmental impact assessment." *The International Journal of Advanced Manufacturing Technology* 34, no. 9 (2007): 1030-1036.

spray water process and sound insulation have been adopted to reduce the adverse impacts of the recycling process.[109]

2.4.3 Processes in Recycling Liquid Crystal Displays

The LCDs are currently a critical technology used when manufacturing TVs and monitors. The LCDs are commonly used in electronics after replacing the Cathode Ray Tube. The recycling of LCD begins with disassembling to recover its material components. The table below shows the compositional analysis of the LCD monitor.

Figure 2.8: Compositional analysis of 15-inch LCD monitor

Table 12.1 Compositional analysis of a 15″ LCD monitor

Support components	kg	LCD panel	kg
Internal steel	1.14	Aluminum back and frame	0.11
Plastics ABS/HIPS	0.79	Plastics	0.44
Electronics	0.30	LCD screen and electronics	0.30
Cables	0.20	Backlights	0.03
Others	0.08	Cables and others	0.01
Total for components	2.51	Total for LCD panel	0.89

Source: Williams and Mcdonnell.[110]

The manual disassembly of LCDs aims at removing the display medium. There should be extensive utilization of metal support structures due to the LCD's fragile nature.[111] The valuable materials recovered from the LCDs are zinc-coated steel, PCBs, cable copper content, aluminum, and optical-enhancement films. The flow diagram below summarizes the disassembly process of LCDs. Dismantling LCD is often challenging because of its fragility. Notably, the EU has

[109] Xiang, Dong, Peng Mou, Jinsong Wang, Guanghong Duan, and Hong C. Zhang. "Printed circuit board recycling process and its environmental impact assessment." *The International Journal of Advanced Manufacturing Technology* 34, no. 9 (2007): 1030-1036.
[110] Williams, Karl S., and T. Mcdonnell. "Recycling liquid crystal displays." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 327-355. Woodhead Publishing, 2019.
[111] Williams, Karl S., and T. Mcdonnell. "Recycling liquid crystal displays." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 327-355. Woodhead Publishing, 2019.

established revised ecological standards for awarding Community Eco-Label to TVs. Manufacturers are required to meet specific requirements for the design to ensure efficient disassembly. The Design for Disassembly include:

- Manufacturers shall not use metal inlays that cannot be separated
- Plastic parts in the LCD shall only be of one polymer and have relevant ISO11469 marking.
- All the fixtures used in the TV like snap fixes and screws shall allow for disassembly
- Information on the hazardous nature of substances in the TV is collected based on the Council Directive 2006/121/EC (1).[112]

Automated disassembly processes for LCDs are being adopted to enhance effectiveness in recycling. After shredding the LCD panel, the components of mercury backlights can be lost in the shred. Monitored processes are initiated to remove the mercury in the fluorescent powder, elemental mercury in the shred, and the mercury combined in the lamp parts.[113] The mercury recovery from the automated disassembly process must indicate the quantified amount of mercury recovered during shredding, the amount generated during shred treatment, and the batch testing method to ascertain that mercury has been removed. Notably, the LCDs contain hazardous materials like mercury-containing backlights, parts with restricted brominated flame retardants, and PCBs.[114] Thus, WEEE recycling must be carefully undertaken to prevent potential harm to the environment and health. Notably, manual disassembly remains the most environmentally and

[112] Williams, Karl S., and T. Mcdonnell. "Recycling liquid crystal displays." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 327-355. Woodhead Publishing, 2019.
[113] Williams, Karl S., and T. Mcdonnell. "Recycling liquid crystal displays." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 327-355. Woodhead Publishing, 2019.
[114] Williams, Karl S., and T. Mcdonnell. "Recycling liquid crystal displays." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 327-355. Woodhead Publishing, 2019.

economically viable option for recycling LCDs. Manual dismantling facilitates the recovery of components without impurities instead of automated recycling that increases the risk of mercury exposure to the environment.[115]

2.4.4 Recycling Refrigerators and Freezers

The WEEE refrigerators and freezers are harmful because they release CFCs when inappropriately disposed of or treated for recycling. A high quantity of refrigeration appliances with high CFC content is still found in most European households. As a result, waste refrigeration appliances are significant hazardous groups within the overall WEEE that pose environmental risks. The Regulation 2037/2000/EC requires that the Ozone-Depleting Substances (ODS) found in refrigerators and air conditioners be recovered to reclaim or recover them before dismantling or disposing of the refrigeration or air cooling equipment.[116] The CFC emissions from the equipment should be avoided by strictly adhering to the WEEE Directive.

The most effective approach to recycling refrigerators is processing the CFCs, HCFC, and HFC within a single recycling plant. Mixed-mode processing can combine the CFC-containing and CFC-free equipment without sorting the WEEE before proper treatment.[117] The method ensures no release of harmful CFC and HCFC that can deplete the ozone layer. Notably, sorting of WEEE fridges and coolers has detrimental effects on the environment. Therefore, the joint procession method in a specified recycling plant should be used to recover ODS adequately. Further, it has become common for most recycling organizations to adapt the designed recycling

[115] Ylä-Mella, Jenni, E. Pongrácz, and R. Keiski. "Liquid crystal displays: material content and recycling practices." In *International Conference on Solid Waste Technology and Management*. Chester, PA, USA: Widner University, 2008. https://www.researchgate.net/publication/264859503_Liquid_Crystal_Displays_Material_Content_and_Recycling_Practices

[116] Keri, Christian. "Recycling cooling and freezing appliances." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 357-370. Woodhead Publishing, 2019. P.362

[117] Keri, Christian. "Recycling cooling and freezing appliances." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 357-370. Woodhead Publishing, 2019. P.362

plants for treating CFC equipment to collect environmentally hazardous CFCs. The waste refrigerators and freezers should be carefully handled by storing them in suitable locations to prevent their hazardous effects on the environment.

2.4.5 Processes in Recovering the Components of Batteries

Recycling used batteries is one of the most robust ways of managing battery wastes. Waste recycling significantly contributes to the benefit of future generations and preserving raw materials. The most common battery recovery methods are pyrometallurgical and hydrometallurgical, adequately described in section 2.3 of this chapter. It is critical to first sort batteries collected to separate those whose treatment cannot be undertaken by a specific process. Notably, most of the battery recycling processes are specifically directed at only a few types of batteries. For instance, a recycling process for treating Zn-C and alkaline batteries may not apply to NiCd batteries.[118] It is essential to note the cost of recycling batteries is often high. Thus, the recycling process may not be commercially viable except for NiMH batteries and therefore only makes sense when there is necessary funding or an urgent need to comply with legal requirements.

2.4.6 Processes in Recovering the Rare Earth Metals from WEEE

Rare earth elements (REEs) are utilized in various consumer products due to their physical and chemical properties. The REEs are present in glass polishing, ceramics, phosphors, permanent magnets, and automotive catalytic converters. Thus, REEs are critical strategic materials in industries like high-tech, defense, and security technology. Recycling REEs is considered for fluorescent material, battery alloys, and magnetic elements used in electrical and electronic equipment.[119] The trichromatic phosphors used in fluorescent lights contribute to 90% of the total

[118] Espinosa, D. C. R., and M. B. Mansur. "Recycling batteries." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 371-391. Woodhead Publishing, 2019.
[119] Tan, Quanyin, and Jinhui Li. "Rare earth metal recovery from typical e-waste." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 393-421. Woodhead Publishing, 2019.

rare earth phosphors. The phosphors have a wide range of commercial applications, thus the need for their recycling.

Other components that can easily be recycled from the fluorescent tubes include aluminum, copper and glass, and hazardous mercury. Recycling fluorescent tubes begin with shredding, followed by air-pushing or end-cutting. Various components like phosphors, mercury, and lamp caps can be recovered after crushing and sieving. A combination of pyrometallurgy and hydrometallurgy is used for the recyclable parts of the fluorescent tube.[120] Heating distillation is applied to recover mercury. Further research is being undertaken on the recycling of REEs in fluorescent tubes. Currently, there are no commercially viable techniques for the recycling process, and in most cases, the waste lamp phosphors are disposed of in landfills.

Conclusion

The chapter has described the e-waste recycling technologies to achieve an e-waste circular economy. Some technologies applied in e-waste recycling have detrimental effects on the environment, as described in this chapter. The application of incineration should be strictly regulated when recycling e-wastes because of the release of toxic residue that pollutes the environment and causes health challenges to the population. Therefore, not all e-waste recycling technologies are eco-friendly. Countries should place safeguards when applying e-waste recycling strategies like incineration to avoid causing further harm to the environment. Further, the incineration residue should be adequately treated to transform it into valuable products, thus reducing landfill hazards.

As discussed in the chapter, advanced technologies should be adopted to recycle e-wastes to achieve an e-waste circular economy in GCC countries. Some of the advanced technologies to

[120] Tan, Quanyin, and Jinhui Li. "Rare earth metal recovery from typical e-waste." In *Waste Electrical and Electronic Equipment (WEEE) Handbook*, pp. 393-421. Woodhead Publishing, 2019.

be applied include mechanical devices like air force sorters and weak flow watercourse separators that separate plastic materials. Thermal treatment technologies that utilize pyrolysis and gasification to recycle waste can also be applied when recycling e-waste in the GCC.

The next chapter will discuss the international environmental law principles that serve as the basis of e-waste laws and management policies. The chapter will discuss various principles applicable to e-waste management such as the prevention, precautionary, cooperation and no harm and the extended producer responsibility (EPR) principles. Notably, the chapter will also discuss various standards of e-waste management in the EU and the United States. Some of the standards discussed in the next chapter include the European Electrotechnical Committee for Standardisation (CENELEC), WEEE Label for Excellence (WEEELABEX), Responsible Recycling (R2) Certification, Electronic Product Environmental Assessment Tool (EPEAT), and Swiss SENS/SWICO Technical Standard.

CHAPTER THREE

INTERNATIONAL ENVIRONMENTAL LAW PRINCIPLES & STANDARDS OF E-WASTE MANAGEMENT

3.0 Introduction

E-waste recycling presents both environmental harm and risk to human health, especially among the population where dumping occurs and the workers dealing with the recycling process. The risks inherent in the handling of e-wastes necessitate the establishment of principles and standards to mitigate the hazardous effect of dealing in e-wastes. These principles and standards are geared towards creating a balance between the economic value of e-wastes and the environmental hazards. As a result, e-waste becomes a commodity for trade and recycling rather than a pollutant. The first part of this chapter deals with some of the existing principles that can ensure the environmentally sound management of e-waste. The second part describes the standards used in labeling and tracking electrical and electronic equipment that become e-waste. Under the first part of this chapter, principles such as prevention, precaution, proximity, and extended producer responsibility are discussed. These principles ensure that e-wastes are handled to mitigate the environmental risks while the economic effects are maximized. For instance, the prevention principle discussed in this chapter does not focus on preventing the generation of e-waste but rather on the proper handling of wastes. In a proper recycling facility, diseases and pollution resulting from handling e-waste are limited by using the best available technologies (BAT).

Additionally, cooperation among nations where e-waste is traded is essential in realizing the total economic value of e-wastes without causing much harm to the environment and human health. This Chapter discusses five international standards and labels that have been developed in the electronics market. These standards include the European Electrotechnical Committee for Standardization (CENELEC), WEEE Label for Excellence (WEEELABEX), R2 Standard,

Electronic Product Environmental Assessment Tool (EPEAT), and Swiss SENS/SWICO Technical Standard.

3.1 Environmental Law Principles

3.1.1 Prevention Principle

The prevention principle derives from the duty of care that a state owes to its neighbors. States must prevent causing significant harm on the territories of other countries or areas beyond their jurisdiction and control. The concept is often referred to as the good neighborliness principle.[121] The concept is part of customary international law that encourages states to undertake due diligence when implementing projects with negative environmental impacts.[122] Thus, the duty encompasses the regulation of private and public activities within the territory of the given state. However, this prevention principle does not impose an absolute duty on a state to prevent all harm. Instead, the principle requires states to prohibit activities that are known to be hazardous.[123]

Depending on the specific legislation under consideration, the duty to prevent includes different requirements.[124] Among other requirements, a state is expected to evaluate the environmental impact of hazardous activities before authorization.[125] The state should equally develop procedures to license or authorize hazardous activities. Such procedures may include setting the conditions for operation and the consequences of violations. Similarly, the state needs to limit emissions and other products or standardize processes. Additionally, a state may employ the best available technology (BAT).[126] Some of these technologies for recycling e-waste have

[121] Kiss, Alexandre, and Dinah Shelton. *Guide to international environmental law*. Brill, 2007.
[122] Atapattu, Sumudu. *Emerging principles of international environmental law*. Brill, 2007.
[123] Techera, Erika, ed. Routledge handbook of international environmental law. Routledge, 2013.
[124] Fitzmaurice, Malgosia, David M. Ong, and Panos Merkouris, eds. *Research handbook on international environmental law*. Edward Elgar Publishing, 2010: 183.
[125] Sands, Philippe, and Jacqueline Peel. *Principles of international environmental law*. Cambridge University Press, 2012: 246- 249.
[126] Kiss, Alexandre, and Dinah Shelton. *Guide to international environmental law*. Brill, 2007.

been discussed in Chapter 2 of this research. Generally, proper environmental impact assessment (EIA) is determinative in examining the due diligence duty of prevention.[127]

The prevention principle is very central to the management of e-waste because some components in electrical and electronic equipment are deemed hazardous. The improper handling of waste electrical and electronic equipment can be very damaging to the environment and humans.[128] It is also to be noted that some equipment contains heavy metals such as mercury, and almost all electronics have plastics.[129] Substances such as mercury are inherently hazardous, and their use is strictly regulated.[130] Plastics also threaten the environment, especially in terms of chlorofluorocarbons (CFC) and hydrochlorofluorocarbons.[131] The table below shows some of the health risks associated with e-waste.

[127] Boyle, Alan, Catherine Redgwell, and Patricia Birnie. *International law and the environment*. Oxford University Press, 2009.
[128] Lundgren, Karin, *The global impact of e-waste: addressing the challenge.* Karin Lundgren; International Labour Office, Programme on Safety and Health at Work and the Environment (SafeWork), Sectoral Activities Department (SECTOR). – Geneva: ILO, 2012, p. 18. Available at: k8https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_196105.pdf
[129] Christine Terada, *Recycling Electronic Wastes in Nigeria: Putting Environmental and Human Rights at Risk*, 10 Nw. J. Int'l Hum. Rts. 154 (2012). http://scholarlycommons.law.northwestern.edu/njihr/vol10/iss3/2
[130] Minamata Convention on Mercury (adopted 9 October 2013, entered into force 18 May 2017) Available at: http://www.mercuryconvention.org/Portals/11/documents/conventionText/Minamata%20Convention%20on%20Mercury_e.pdf
[131] Stockholm Convention on Persistent Organic Pollutants (adopted 22 May 2001, entered into force 17 May 2004) 2256 UNTS 119. Available at: http://chm.pops.int/Portals/0/Repository/convention_text/UNEP-POPS-COP-CONVTEXT-FULL.English.PDF

Table 3.1: **E-waste recycling and associated risks for human health**

Metals and some of their compounds	Human health risk
Antimony	Irritation of the eyes, skin and lungs
Bismuth	Skin problems and depression
Cadmium	Lung damage, bone fracture, damage to central nervous system, cancer, possibly DNA damage
Chromium	Lung cancer, kidney and liver damage
Cobalt	Vomiting, loss of vision, heart issues, thyroid damage, cause of asthma
Gallium	Throat irritation, breathing problems, chest pains
Germanium	Negative impact on skin, eyes and blood
Molybdenum	Joint pains in knees, hands and feet
Nickel	Lung cancer, nose cancer, heart disorders
Selenium	Abdominal pain, fever, heart and muscle problems, bronchial asthma, diarrhoea, enlarged liver, burning, bronchitis, sore throat
Silver	Brain damage, kidney, eye, lung, and liver associated problems
Lead	Reduced fertility of men, rise in blood pressure, kidney damage, miscarriages, brain damage, diminished learning abilities of children
Tin	Eye and skin irritations, sickness and dizziness, breathlessness, urination problems, headaches
Iron	High risk of lung cancer
Yttrium	Negative impact on liver
Zinc	Vomiting, skin irritations, decreased sense of taste and smell, birth defects, stomach cramps

Source: *International Labor Organization* (March 2019)[132]

Therefore, improper handling of e-waste can lead to great suffering among workers and the neighboring community who may suffer from lead poisoning, respiratory diseases, and contaminated soil and water.[133] For instance, pollution in Nigeria, China, and India has been caused by poor management of e-waste. When recycling printers, workers dealing in e-waste in

[132] ILO: *Decent work in the management of electrical and electronic waste (e-waste)*, GDFEEW/2019, Issues paper for the Global Dialogue Forum on Decent Work in the Management of Electrical and Electronic Waste (E-waste) (Geneva, 9–11 April 2019). https://www.ilo.org/sector/activities/sectoral-meetings/WCMS_673662/lang--en/index.htm

[133] Orisakwe, Orish Ebere, Chiara Frazzoli, Cajetan Elochukwu Ilo, and Benjamin Oritsemuelebi. "Public health burden of e-waste in Africa." *Journal of Health and Pollution* 9, no. 22 (2019). Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6555250/#i2156-9614-9-22-190610-b34

Lagos, Nigeria, reportedly contracted respiratory diseases, skin irritation, and chronic cough and coryza. The respiratory diseases were related to the inhalation of toner dust from photocopiers and other equipment containing phosphorus.[134] Another study reported that Nigerian patients were predisposed to immunotoxicity and brain-related disorders resulting from the improper handling of e-waste. Further, there were high traces of heavy metals in patients with Parkinson's disease who were residents in areas where e-wastes were either recycled or dumped.[135]

Similar findings were made in Ghana, where there was high soil pollution resulting from e-wastes dumpsites.[136] Researchers linked high levels of polychlorinated biphenyls (PCBs) and polychlorinated dibenzofurans (PBDF)in human breast milk to health risks, including neurodevelopmental deficits and cancer.[137] However, there is a duty to prevent such damages both to humans and to the environment. It is imperative to establish an environmental impact assessment tool for e-waste handling companies and informal sectors. The intervention will act as a preventive measure towards the pollution of the environment by e-wastes and the adverse effects the chemicals may have on human health.

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[134] Manhart, Andreas, Oladele Osibanjo, Adeyinka Aderinto, and Siddharth Prakash. "Informal e-waste management in Lagos, Nigeria–socio-economic impacts and feasibility of international recycling co-operations." *Final report of component* 3 (2011): 24. Available at: http://www.basel.int/Portals/4/Basel%20Convention/docs/eWaste/E-waste_Africa_Project_Nigeria.pdf

[135] Ogunrin, A. O., M. A. Komolafe, E. O. Sanya, C. Osubor, O. A. Ajose, A. A. Akande, and S. K. Mosaku. "Trace metals in patients with Parkinson's disease: a multi-center case-control study of Nigerian patients." *J Neurol Epidemiol* 1, no. 1 (2013): 31-38. Available at: http://dx.doi.org/10.12974/2309-6179.2013.01.01.4

[136] Otsuka, Masanari, Takaaki Itai, Kwadwo Ansong Asante, Mamoru Muto, and Shinsuke Tanabe. "Trace element contamination around the e-waste recycling site at Agbogbloshie, Accra City, Ghana." *Interdiscip Stud Environ Chem Environ Pollut Ecotoxicol* 6, no. 6 (2012): 161-167. Available at: https://www.terrapub.co.jp/onlineproceedings/ec/06/pdf/PR620.pdf

[137] Asante, Kwadwo Ansong, Sam Adu-Kumi, Kenta Nakahiro, Shin Takahashi, Tomohiko Isobe, Agus Sudaryanto, Gnanasekaran Devanathan et al. "Human exposure to PCBs, PBDEs and HBCDs in Ghana: Temporal variation, sources of exposure and estimation of daily intakes by infants." *Environment international* 37, no. 5 (2011): 921-928. Available at: https://www.resource-recovery.net/sites/default/files/human_exposure_to_pcbs_pbdes_and_hbcds_in_ghana.pdf

3.1.2 Precautionary Principle

The precautionary principle is at the core of environmental law and waste management. Ideally, the principle encourages states to take regulatory actions that prevent harm to the environment or human health where there is no satisfactory scientific truth of such risks. States are required to evade the risks of catastrophic harm to human health and the environment, especially where the possibility of such harm occurring is real but with no certainty of its effects due to the limited scientific knowledge at the time.[138] There are instances where this principle has been considered as part of international customary law even though such findings remain highly contested. Notably, this principle would apply best when contemplated in treaty law rather than non-binding instruments such as declarations. The present study's primary concern is to demonstrate the precautionary principle in ensuring seamless trade in e-waste to enable recycling and safeguarding the environment and human health.

The precautionary principle is authoritatively detailed under Principle 15 of the 1992 Rio Declaration of the United Nations Conference on Environment and Development ("UNCED") (the Rio Declaration). Principle 15 of the Rio Declaration requires countries to comprehensively apply a precautionary initiative based on their capabilities to safeguard the environment. Thus, states should not rely on the lack of scientific certainty to postpone taking cost-effective measures in preventing environmental harm, especially during threats of severe or irreversible harm. This provision contains four main elements in the regulation of environmentally harmful substances and activities. First, there must be a trigger with some degree of uncertainty about future harm that necessitates regulation of inherently harmful activities or substances. This element of trigger incorporates two sub-elements that must be placed into consideration. The seriousness of future

[138] Atapattu, Sumudu. *Emerging principles of international environmental law*. Brill, 2007. Pp. 203 – 204.

harm must be considered alongside the quality and quantity of the available information pointing to the foreseeability of serious harm.

Secondly, the precautionary principle consists of a timeframe between predicting the possibility of harm and when a state chooses to regulate the possible harm. The timing element is the core of the precautionary principles. It encourages states to take regulatory actions before the harm happens and before uncertainties of the harm can be resolved. Notably, the precautionary principle transcends the prevention of known risks. The prevention principle would only require actions to be taken with regards to scientifically proven risks. However, precaution involves a timely regulation for possible harms whose details are yet to be conclusively proved.[139]

The third element of the principle is the response that the state must take, awaiting scientific certainty on the harm. It may well be appropriate to forgo an activity or forgo some technology as a precaution to severe harm. However, no specific regulatory measure is enlisted in the principle. Thus, other factors such as risk trade-offs, the seriousness of the harm, and the costs of the measures may be determinative in the enforcement of this principle. Lastly, the process needs to be repetitive and continuous in line with scientific knowledge and risks. The burden to prove the availability of new information, the person to avail the information, the time, and the certainty of such information remains debatable. Nonetheless, the precautionary principle gives rise to procedural and substantive obligations to address the risk of serious harm before it happens.

3.1.3 Cooperation

Cooperation among states is a fundamental principle of international environmental law. It forms part of the good neighborliness principle and seeks a common approach to environmental

[139] Nanda, Ved, and George Rock Pring. *International environmental law and policy for the 21st century*. Martinus Nijhoff Publishers, 2012. P. 61.

issues.[140] Many multilateral environmental agreements require states to cooperate in achieving the objectives of such agreements. Principle 24 of the Stockholm Declaration noted that cooperation among states is essential in preventing, controlling, reducing, and eliminating adverse environmental effects. The cooperation envisaged by the Stockholm Declaration takes account of the sovereignty and interests of all states.

Similarly, Principle 5 of the Rio Declaration encourages increased cooperation to eliminate poverty. Equally, Principle 27 of the Rio Declaration provides that cooperation should be undertaken in good faith and encompass the development of international law in sustainable development. More substantively, Principle 14 of the Rio Declaration encourages countries to cooperate to mitigate the transboundary movement of hazardous substances.

3.1.4 Proximity Principle

The proximity principle internalizes the adverse effects of 'waste tourism' through the localization of waste treatment infrastructures.[141] Waste tourism is a common phenomenon whereby companies, especially those from developed countries, export their waste to the most lenient legal regulations. The proximity principle implies that the effects of wastes should be reduced to their proximate cause. Ideally, waste should be disposed of closer to its source. Therefore, the proximity principle is intended to prevent the environmental impacts of wastes to persons not responsible for their generation. The polluter should bear the cost of managing the pollution that they have caused.

[140] Nanda, Ved, and George Rock Pring. *International environmental law and policy for the 21st century*. Martinus Nijhoff Publishers, 2012. Pp. 21 -23.
[141] Jean-Baptiste Bahers, Mathieu Durand. THE EFFECT OF PROXIMITY ON WASTE MANAGEMENT IN THE PARADOXES OF THE CIRCULAR ECONOMY IN FRANCE (CHAPTER NINE). Perspectives on Waste from the Social Sciences and Humanities. Opening the Bin (Editor Richard Ek and Nils Johansson), Cambridge Scholars Publishing, 2020, 978-1-5275-4674-5.

Further, the proximity principle seeks to limit the environmental costs of transporting waste. Transporting wastes have a severe environmental impact and may carry additional costs in spillage and related ham. Thus, the proximity principle seeks to limit the impact of hazardous waste during transportation. Thirdly, the proximity principle envisions decentralized waste management as opposed to a centralized responsibility. This interpretation of the principle likens it to the principle of subsidiarity. In other words, household and hazardous wastes are best managed at the municipal or regional level instead of national and international levels. The municipalities or smaller regions are expected to implement self-sufficiency in waste disposal. A municipality/ state where hazardous waste is generated must implement the proximity principle with attention to territorial self-sufficiency in raw materials and waste-treatment infrastructures.

The proximity principle has become an obligation on states, especially concerning hazardous waste management. However, its utility in recycling wastes at the local and international levels has not gained much discussion among scholars. Nonetheless, the proximity principle serves two critical functions. First, the proximity principle acts as a tool for the planning of waste management facilities. Secondly, it raises awareness in the local communities concerning the burdens of the waste that such communities produce to avoid passing it over to others.

3.1.5 Extended Producer Responsibility (EPR)

Extended producer responsibility (EPR) is a concept that derives from the polluter pays principle (PPP). Under the Polluter Pays Principle, parties generating wastes should meet the costs of managing the pollution caused by their waste products.[142] The extended producer principle seeks to decrease the total environmental effects from a product by ensutring that manufacturers take responsibility for the entire product life-cycle through take-back, recycling, and final disposal.

[142] Atapattu, Sumudu. *Emerging principles of international environmental law*. Brill, 2007.

Therefore, the EPR shifts the burdens of waste management from the government to the manufacturer and discourages the production of hazardous products.[143] The cost of hazardous products is often high because it incorporates the treatment and disposal costs.

3.2 Standards for E-Waste Management

3.2.1 European Electrotechnical Committee for Standardisation (CENELEC)

The CENELEC is responsible for standardization in the electronic engineering field regarding electronic waste management. The body plays a pivotal role in e-waste management by preparing voluntary standards that promote trade between nations, establish new markets, and reduce compliance costs. CENELEC fosters innovation and competitiveness and makes technology available through voluntary standards.[144] The European standards are established to encourage technological development, ensure interoperability, guarantee the safety and health of consumers, and promote environmental health protection.

CENELEC significantly contributes to e-waste management through standardization. The body develops standards in a more mature, predictable, and efficient process. As a result, innovators have the opportunity to demonstrate their value by following the specified standards on electrical and electronic products. Further, the body ensures that innovators participate in the standardization process and create a robust infrastructure for innovation. Notably, standards are critical in strengthening environmental regulation by ensuring that electronic equipment meets the environmental safety requirements.

Further, standards promote safety and environmental protection. The standardization process establishes basic rules for safe and environmentally-friendly management of e-waste and

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[143] Schumacher, Kelsea A. *Electronic waste management in the US Practice and policy*. University of Delaware, 2016: 66. Available at: https://udspace.udel.edu/bitstream/handle/19716/20333/2016_SchumacherKelsea_PhD.pdf?sequence=1&isAllowed=y

[144] CENELEC. "CENELEC." Welcome to CENELEC – European Committee for Electrotechnical Standardization. Accessed May 25, 2021. https://www.cenelec.eu/aboutcenelec/whoweare/index.html.

ensuring that companies comply with the environmental safety rules. The CENELEC standards are universal because they align with international standards such as International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), and International Telecommunication Union (ITU-T).

3.2.2 WEEE Label for Excellence (WEEELABEX)

The WEEELABEX project developed new standards for managing waste electrical and electronic equipment like laptops, computer accessories, TV sets, fridges, and cell phones. The WEEE is currently one of the fastest-growing waste streams in the EU and is anticipated to generate over 12 million tonnes by 2020.[145] The WEEELABEX is significant in e-waste management because it develops new solutions to raise awareness on the need for ensuring appropriate WEEE collection. It recommends testing reuse possibilities, optimizing treatment and recycling, creating quality standards and evaluation, offering training to professionals, and developing information systems and exchanges.[146] Notably, the WEEELABEX develops new standards for the WEEE recycling processes and trains auditors that ensure all the required standards are adequately evaluated and communicated through the WEEE Label of Excellence.

The WEEELABEX standards establish measures associated with protecting the environment and human health by preventing adverse impacts of e-waste treatment. Further, the WEEELABEX is instrumental in e-waste management by defining operators' technical and management requirements to meet the e-waste treatment standards. Under the administrative and organizational requirements, an operator must adhere to the European Community laws and the corresponding transposition. Further, the operator must maintain compliance records relating to

[145] European Union. "LIFE & Electrical and electronic waste management (WEEE)." Last modified 2016. 2-4. https://ec.europa.eu/environment/archives/life/products/download/factsheet_weee_web.pdf.
[146] European Union. "LIFE & Electrical and electronic waste management (WEEE)." 2-4.

the legal and regulatory obligations.[147] Notably, legal compliance is one of the appropriate measures to ensure robust electronic waste management to improve health and quality of life. Therefore, documenting compliance with legal and regulatory activities on-site is critical in assessing and monitoring progress in e-waste management. Further, an operator is expected to create a procedure for identifying legal obligations applicable to the environment, health, and safety.

The WEEELABEX also highlights the management principles of e-waste recycling and treatment. An operator must ensure that an effective management system for all health, safety, environmental, and quality activities. Further, an operator should ensure continuous enhancement of their activities through an evaluation and management process. [148] The management principles are pivotal in ensuring that e-waste generators and handlers stick to the best practices when recycling and treating wastes to reduce potential environmental harm.

The WEEELABEX standards contribute to efficient e-waste management by requiring the treatment operator to achieve the recycling and recovery targets established in Directive 2002/ 96/ EC. [149] Article 7 of the Directive regards recovery where EU countries are expected to ensure that manufacturers establish systems on an individual and collective basis according to the community legislation and encourage WEEE recovery. [150] The member states must prioritize the reuse of electrical and electronic appliances. As a result, the standard is critical in making the best use of e-wastes through recycling and recovery to eliminate potential environmental harm. Further, batch

[147] WEEELABEX. "Normative document. WEEELABEX." Last modified 2013. 7-8. https://www.weeelabex.org/wp-content/uploads/2019/10/weeelabex_v10-0_standard_on_treatment.pdf.
[148] WEEELABEX. "Normative document. WEEELABEX." 7-8.
[149] WEEELABEX. "Normative document. WEEELABEX." 12-13.
[150] EU. "DIRECTIVE 2002/96/EC OF The European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE)." Last modified 2003. 29-30. https://eur-lex.europa.eu/resource.html?uri=cellar:ac89e64f-a4a5-4c13-8d96-1fd1d6bcaa49.0004.02/DOC_1&format=PDF.

processing should be undertaken at least once every two years per site to determine the recycling and recovery rates.

The WEEELABEX treatment requirement specifies standards for preparing for the reuse of e-waste materials. An operator that engages in preparation for reuse activities must obtain permits from authorities. [151] Further, the operator must adhere to the European standards for processing the UEEE and WEEE to guarantee safety and ensure robust recycling and reuse of e-waste. The required infrastructure and trained personnel should be availed to test equipment and preparation for reuse procedures and documentation.

3.2.3 R2 Standard

The Responsible Recycling (R2) Certification standard for electronics repair and recycling offers a standard set of processes, safety mechanisms and documentation needs for organizations that repair and recycle used electronics. The US Environmental Protection Agency requires all electronics recyclers to be certified after meeting the standards for safe recycling and e-waste management. The certification is critical in promoting safe recycling since recyclers adhere to the set recycling standards to enhance environmental safety. [152] Further, the certification initiatives share common elements for responsible recycling of used electronics.

Under the R2: Requirements, an e-waste recycler must possess and use an Environmental Health and Safety Management System (EHMS) for planning and monitoring its environmental, health, and safety practices, including all the activities undertaken to comply with every requirement of the R2:2013 Standard. The requirement ensures that electronic recyclers establish a robust environmental, health, and safety management system that facilitates appropriate e-waste recycling to prevent environmental pollution and risks to users. Further, an electronics recycler

[151] WEEELABEX. "Normative document. WEEELABEX." 8-9.
[152] Ministry of Environment. *Standards for Collection, Storage, Transport, Recovery, Treatment and Disposal to Ensure Environmentally Sound Management of E-waste*. n.d. 4-5. https://www.files.ethz.ch/isn/168844/3R_06.pdf.

must document all the scope of operations encompassed in the R2:2013 and EHSMS certifications to enable assessment and monitoring of the recyclers' conformity to the safe recycling procedures and standards. Only an independent body shall certify the e-wastes recyclers to ensure safety and environmental protection during electronic waste recycling. [153] The certification by accredited and independent auditors will assure that a recycler has followed the due processes and there are no mistakes during the recycling process to promote safety and environmental protection.

According to the R2: 2013 Requirements, every electronics recycler must create and comply with a policy for managing the used and end-of-life electronic equipment based on the reuse, recovery hierarchy of the responsible management strategies. The reuse and recovery strategies are essential elements of e-waste recycling and management that ensure the best use of e-wastes generated for various purposes that serve the human need, thus limiting their disposal that may be costly to the environment. [154] Therefore, e-waste recyclers should be committed to taking all practical steps to direct electronic equipment and components for reuse and resale to protect the environment from electronic wastes that may be hazardous. Further, the electronic waste recyclers must take appropriate measures to ensure that equipment that can be repaired and reused is directed to qualified persons for refurbishment rather than disposal.

On materials recovery of the R2: 2013 Requirements, all electronic recyclers are expected to undertake practical measures towards separating materials in electronic equipment and components through manual dismantling or, in some cases, where appropriate, mechanical processing. The procedure should be taken for used electrical and electronic equipment not directed to reuse or refurbishment. The materials should be taken to properly-equipped materials

[153] SERI. "The Responsible Recycling (“R2”) Standard for Electronics Recyclers." Last modified 2013. 4-5. https://sustainableelectronics.org/wp-content/uploads/2020/12/R2-2013-Standard-ENGLISH.pdf.
[154] SERI. "The Responsible Recycling (“R2”) Standard for Electronics Recyclers." 4-5.

recovery facilities to recover them for use rather than disposal that may be costly and harmful to the environment. Further, R2:2013 requires that all recyclers avoid directing e-waste material to incineration, energy recovery, or land disposal unless there are no recycling and reuse options. Thus, recyclers must take due considerations before directing electronic materials to energy recovery or incineration to ensure that all the viable options for recycling and reuse are exploited. The directive is essential in promoting the prioritization of the responsible e-waste management hierarchy by ensuring reuse before recovery.

Under the Legal Requirements of the R2:2013, e-waste recyclers must adhere to the applicable environmental health and safety and data security legal requirements. Electronic materials should be imported and exported according to the laws applicable in the importing, transit, and exporting countries. [155] As a result, electronics recyclers must create a robust legal compliance framework for shipping untested and non-functioning equipment or components with Focus Materials. Further, recyclers must maintain facility compliance by identifying and documenting the recycling operations' environmental, health, safety, and data security requirements.

On Focus Materials, an electronics recycler is required to manage on-site and in the selection of downstream vendors, the Focus Materials passing through the facility in ways that are protective to the facility workers. Further, the Focus Materials should be handled on-site in ways consistent with protecting public health and the environment. Notably, due diligence must be undertaken on downstream vendors to ensure that the shipment of Focus Materials does not carry potential harm to the environment. The requirements are critical in ensuring responsible management of Focus Materials when dealing with electronic wastes to facilitate proper e-waste

[155] SERI. "The Responsible Recycling ("R2") Standard for Electronics Recyclers." Last modified 2013. 5-6. https://sustainableelectronics.org/wp-content/uploads/2020/12/R2-2013-Standard-ENGLISH.pdf.

management. A robust Focus Materials management plan can be developed to guide e-waste recyclers on effectively managing the Focus Materials to protect the environment and guarantee people's safety. [156] A recycler should analyze, plan, and undertake a regular review of the materials' handling within the facility and throughout the e-waste recycling chain. Further, the Focus Materials management plan is critical in e-waste recycling since it specifies how a recycler and associated downstream vendors will conform to the requirements.

The R2: 2013 Requirements is critical in e-waste management by specifying the procedures for removing Focus Materials. The materials must be removed using safe and effective mechanical processing or manual dismantling before shredding or materials recovery of equipment or components.[157] However, e-waste materials with mercury are to be excluded from the procedure to mitigate the release of toxic wastes to the environment and avoid potential harm to on-site workers. Notably, e-wastes with mercury are too small to be removed safely at reasonable costs. Further, workers must be protected from the adverse health risks resulting from mercury handling. Therefore, appropriate measures must be taken when recycling e-wastes containing mercury to avoid harming people and undermining environmental protection.

Further, regarding the processing, recovery, and treatment of Focus Materials, e-waste recyclers must send the removed materials to processing, recovery, and treatment facilities while adhering to all the regulatory standards. Appropriate technology and systems should be employed to send the removed Focus Materials for processing and recovery safely. Focus Materials that should be handled with technology include items containing mercury, circuit boards where removal of batteries and mercury is necessary, and other items with polychlorinated biphenyls

[156] SERI. "The Responsible Recycling (“R2”) Standard for Electronics Recyclers." 8.
[157] SERI. "The Responsible Recycling (“R2”) Standard for Electronics Recyclers." 8.

(PCBs). [158] Notably, technology specifically designed to remove the PCB should be used to safely and effectively handle the e-wastes.

Recyclers are required to undertake due diligence when selecting downstream vendors for moving Focus Materials to facilitate safe and environmentally-friendly management of e-waste. Specifically, the shipment of removed Focus Materials and electrical equipment or components containing FMs should be undertaken with careful consideration and conformity with the recycler's Focus Material management plan. The strict adherence to the documented system for managing environmental, health, and safety risks are pivotal for effective management of e-waste with Focus Materials. The recyclers must ensure that all the vendors conform to the standards requiring effective handling and shipment of Focus Materials stated in Provision 5 of the R2 2013 Standard.

Provision 6 of the R2 Standard is also critical in the efficient management of e-wastes since it guides recyclers to handle reusable equipment and components. Notably, recyclers must repair and refurbish, adequately test and package reusable electrical equipment and components to promote continued use and responsible recycling of Focus Materials. [159] As a result, the provision facilitates proper management of e-waste by enhancing their reuse rather than disposal that could harm the environment. However, the reuse of equipment or e-waste components must only be undertaken to adhere to the commercial agreements with parties with whom the equipment is received. Further, the equipment and components must undergo thorough testing to determine if they are fully functional and ready for use before they are reused. The directive is critical in ensuring health and safety, and environmental protection when reusing e-waste products. The tests seek to confirm if the equipment or components are working correctly and adequately configured with the legally licensed software for their operations.

[158] SERI. "The Responsible Recycling (“R2”) Standard for Electronics Recyclers." 8.
[159] SERI. "The Responsible Recycling (“R2”) Standard for Electronics Recyclers." 11.

3.2.4 Electronic Product Environmental Assessment Tool (EPEAT)

The Electronic Product Environmental Assessment Tool is an international ecolabel that applies in the IT sector. The EPEAT assists buyers, manufacturers, resellers, and others to buy and sell environmentally friendly electronic products.[160] The EPEEAT was established using a grant from the US Environmental Protection Agency and is managed by the Global Electronics Council. [161] Electronic products registered by the EPEAT must meet the environmental performance criteria that involve material selection, supply chain greenhouse gas (GHG) emissions reduction, product design for circularity, product longevity, energy conservation, and end-of-life management. The products covered by EPEAT include computers and displays, imaging equipment, photovoltaic modules and inverters, TVs, servers, and mobile phones.

The EPEAT is instrumental in e-waste management by perfecting the electronic waste recycling process through the labeling system. A robust recycling process is necessitated by comprehensive, analytical, and trustworthy labels and certifications that assist industry, producers, suppliers, and buyers in identifying recycled electronic products that meet the highest social, environmental, and energy sustainability standards. [162] Therefore, the EPEAT is an ecolabel tool for the IT industry that mainly deals with electrical and electronic products. The ecolabel is designed to assist purchasers in making informed decisions when buying electronic products and recycled electronics. Further, manufacturers and recyclers can be recognized for their vision and innovation to create sustainable recycled electronic products. The EPEAT contributes to e-waste management through recycling by focusing on the labeling and certification of post-consumer

[160] Africa Clean Energy Technical Assistance Facility. "E-Waste Policy Handbook Africa Clean Energy Technical Assistance Facility. 2019. E-Waste Policy Handbook." Last modified 2019. 22-23. https://www.ace-taf.org/wp-content/uploads/2019/11/ACE-E-Waste-Quick-Win-Report20191029-SCREEN.pdf.
[161] EPA. "Electronic Product Environmental Assessment Tool (EPEAT)." US EPA. Last modified March 18, 2021. https://www.epa.gov/greenerproducts/electronic-product-environmental-assessment-tool-epeat.
[162] Lalonde, Paul. "EPEAT: Helping Buyers Make Sustainable Decisions." Lavergne. Last modified February 17, 2021. https://lavergne.ca/industry-trends/epeat-helping-buyers-make-sustainable-decisions/.

recycled electronic products, responsible end-of-life management, product longevity, and preferable materials use.

The EPEAT registration ensures that the recycling of electronic wastes meets a set of criteria and standards to promote environmental sustainability and people's health. Notably, the EPEAT registration is premised on a comprehensive set of standards established through consultation with electronic industry players and other stakeholders. Every recycled product category includes the required and optional criteria. The standards are the EPEAT baseline requirements that products must meet to be listed on the EPEAT registry. [163] However, recyclers can surpass the baseline standards to meet the optional standards to improve their sustainability rating.

Notably, there are gold, silver, and bronze registration levels that a recycler can meet. EPEAT Bronze level is achieved when the recycled products meet all the needed criteria but achieve less than 50% of the optional standards. Recyclers can attain EPEAT Silver after meeting the baseline standards and achieving 50%-74% of the optional criteria. [164] Finally, the EPEAT Gold is attained when a recycler of electronic waste meets the baseline criteria and 75%-100% of the optional standards. Notably, the standards to be met are comprehensive to ensure adequate management of e-wastes leading to the protection of the environment. For instance, the computers and displays category requires that all products should be made with minimum post-consumer recycled plastic ITE-derived post-consumer recycled plastic or bio-based content (4.2.1.1), plastic parts compatible with recycling (4.3.2.1), and plastic parts separable for recycling (4.3.2.2).

[163] Lalonde, Paul. "EPEAT: Helping Buyers Make Sustainable Decisions."
[164] Lalonde, Paul. "EPEAT: Helping Buyers Make Sustainable Decisions."

3.2.5 Swiss SENS/SWICO Technical Standard

The SENS/SWICO is the official technical standard of Switzerland which came into force on 8th December 2009. The standard applies to the recycling of WEEE in Switzerland. [165] It complements the existing regulatory framework through its general technical and detailed directives for recycling electronic equipment. The SENS/SWICO recycling standards apply to electrical appliances in computing, consumer electronics, office equipment, telecommunications, and medical instruments. Some electrical products regulated by the standards are copiers, printers, TVs, MP3 and MP4 players, mobile phones, and cameras. The SENS/SWICO recycling standards focus on removing electrical and electronic components with harmful substances and ensuring their appropriate recycling. [166] As a result, the standards contribute to the safe recycling of e-waste as harmful materials are removed.

Notably, only unrecyclable materials are converted into energy through thermal recycling procedures. The unrecyclable e-waste materials converted to energy are a critical source of energy for industrial activities leading to their proper use rather than disposal that may cause harm to the environment. Converting materials to energy also saves on energy and promotes environmental sustainability, which is one of the aims of e-waste management. During recycling, removing pollutant materials involves manual and mechanical separation of electrical appliances into different recyclable material and pollutant fractions.[167] The manual extraction of harmful materials is pivotal in the recycling procedures as all the valuable appliance parts are separated from

[165] SRI. "Technical and environmental standards for the treatment of WEEE Comparison of WEEE-Standards from Switzerland, Europe and the US." Last modified 2015. 4-5. https://sustainable-recycling.org/wpcontent/uploads/2015/07/SRI_ComparisonStandards_2015en.pdf.

[166] *Report of the Technical Inspectorate SENS, SWICO Recycling, SLRS*. 2011. 5-6. http://www.rezagos.com/downloads/Informe-RAEE-SUIZA.pdf.

[167] *Report of the Technical Inspectorate SENS, SWICO Recycling, SLRS*. 2011. 8.

pollutant components to enable continued utilization. Therefore, pollutant removal is one of the highest priorities of SENS/SWICO.

Conclusion

This chapter has provided an in-depth discussion of the international principles and standards that regulate the management of e-waste. The principles and standards are pivotal in creating a balance between the economic value of e-waste and environmental hazards. Thus, by applying the principles and standards, e-wastes are transformed into commodities for reuse and trade rather than pollutants. One of the fundamental principles regarding e-waste management discussed in this chapter is the prevention principle which relates to the obligation of every state to mitigate causing possible harm to the environment. As discussed in this chapter, the principle of prevention can be applied in the GCC to manage e-wastes effectively without causing harm to the environment. Therefore, every GCC state should undertake due diligence when implementing projects with adverse implications to the environment.

The precautionary principle calls for the evasion of environmental risks among the GCC countries in response to e-waste management. The principle is applicable in ensuring an e-waste circular economy by requiring states to take precautionary measures to eliminate e-wastes that pose potential harm even in cases where there is no satisfactory scientific truth for the risks. The Extended Producer Responsibility principle discussed in the chapter is critical in ensuring an e-waste circular economy in the GCC. The GCC member states can enforce laws that require e-waste generators to incur the costs of controlling pollution resulting from e-wastes generated.

Extended producer responsibility (EPR) is a policy that derives from the polluter pays principle (PPP). Under the polluter pays principle, those who generate wastes should meet the

costs of managing the pollution caused by their products.[168] The extended producer principle aims to decrease the total environmental impact from a product by making the product's manufacturer responsible for the entire life-cycle through take-back, recycling, and final disposal. This chapter has also discussed standards that the GCC countries can adopt to manage e-wastes. One of the standards is CENELEC that involves the standardization in the electronic engineering field regarding electronic waste management. The body plays a pivotal role in e-waste management by preparing voluntary standards that enable trade between nations, create new markets, and reduce compliance costs. The other standard is the WEEELABEX which establishes the measures associated with safeguarding the environment and human health and ensuring safety by mitigating adverse impacts of e-waste treatment. Further, the R2, a standard for electronics repair and recycling, is crucial in establishing processes, safety measures, and documentation that should be followed by enterprises that repair and recycle used electronics. The standards are essential in achieving the e-waste circular economy since they offer processes and requirements to minimize e-waste discharge in the environment while maximizing their economic benefits.

Having discussed the principles and standards relating to e-waste management that can be applied in the case of the GCC member states, the next chapter will look at the global trends in e-waste production and management. The chapter will analyze the processes of discovering the economic value of e-waste by first discussing the steps of quantifying e-waste and collecting e-waste. The next chapter will offer insights into the e-waste handling mechanisms by using data from the Global E-waste Monitor reports of 2014, 2017, and 2020.

[168] Atapattu, Sumudu. *Emerging principles of international environmental law*. Brill, 2007.

CHAPTER FOUR

GLOBAL TRENDS IN E-WASTE PRODUCTION AND MANAGEMENT

4.0 Introduction

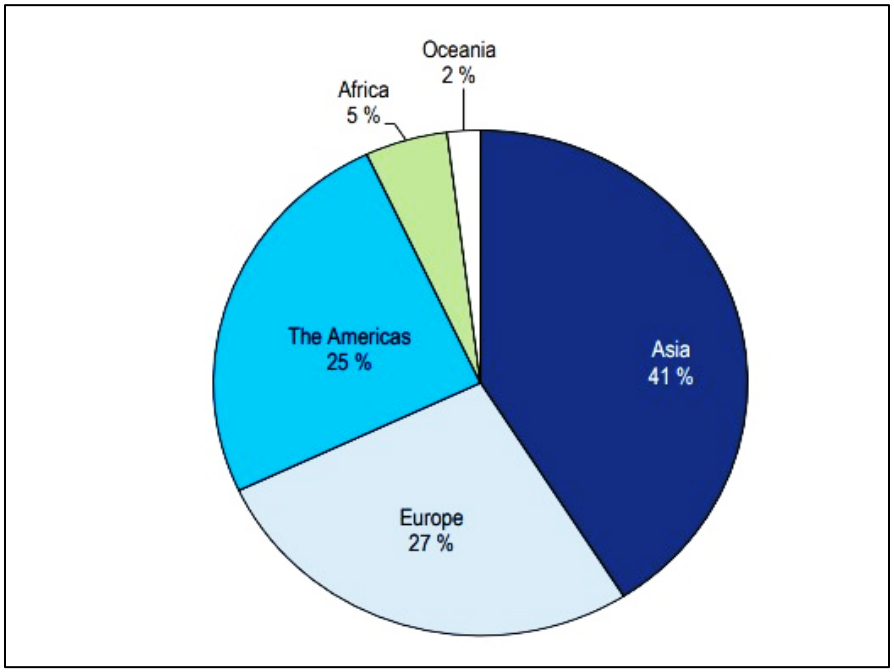
The different dynamics of electronic wastes present a challenge to realizing the value contained in obsolete electronics. Most of the used electronics lie idle in landfills, and some are incinerated in municipal incinerators worldwide. Although there is information about the precious metals in used electronics, recycling such electronics has remained a challenge for most countries. This chapter looks at what it takes to discover the economic value of e-waste. The analysis in this chapter starts by discussing the steps of quantifying e-wastes. The initial stage involves monitoring the sales and consumption of electronics at the market entry phase. The electronics are monitored through the stock phase, where they undergo their residential lifetime. After the electronics become obsolete to the last owner, they are discarded and become e-waste. Data from all these stages must be collected and harmonized at the municipal level, followed by the collection e-wastes. Some e-wastes may be collected from the official take-back system through the Extended Producer Responsibility discussed in Chapter 3. Other e-wastes may find themselves mixed with other household wastes and either go into landfills or municipal incinerators. Equally, other e-wastes may be handled outside the official take-back system and remain unaccounted for municipally and internationally. This chapter employs tables and figures to discuss the global value of e-wastes and the trends in e-waste generation and recycling. Most of the statistics in this chapter are obtained from three official reports of the Global E-waste Monitor; 2014, 2017, and 2020. In some instances, other statistics and forecasts are used to compare the official data contained in the Global E-waste Monitor reports.

4.1 Turning Wastes into Gold: Internalizing the Externalities of Hazardous E-wastes

Used electrical and electronic equipment contains valuable materials with economic impacts when adequately recycled. However, the economic value is dependent on other aspects,

including the production level of electronic wastes, consumption of electronics, pollution, and labor costs. It is estimated that approximately 50 million metric tonnes of e-waste are produced yearly.[169] In 2016 alone, the Global E-waste Monitor 2017 noted that 44.7 million metric tonnes of e-waste were generated across the globe.[170] Notably, 44.7 million metric tonnes of e-waste are equivalent to every person producing just over six kilograms of e-waste. **Figure 4.1.** demonstrates the e-waste generation per region for the year 2016.

Figure 4.1. E-waste generated in 2016, by region



Source: Baldé et al.: *The Global E-waste Monitor 2017*[171]

The high volume of e-waste has a positive effect on the economy when adequately recycled. The e-waste contains valuable materials such as gold, platinum, cobalt, rare earth, and

[169] *Global E-waste reaches record high, says new UN report*. (2020, January 17). TCO Certified. https://tcocertified.com/news/global-e-waste-reaches-record-high-says-new-un-report/
[170] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017). https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf
[171] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017). https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

high quantities of aluminium and tin that can be recycled to manufacture other valuable products.[172] For instance, research shows that e-waste contains approximately 7% of the world's gold, and the trend has increased with more recycling of e-waste.[173] In 2014, the Global E-Waste monitor reported that the gold content from e-waste in 2014 was about 300 tonnes, representing 11 per cent of the global gold production from mines in 2013 (2770 tonnes).[174]

However, the value of precious metals from e-waste can only be realized through proper recycling technologies. For example, improper handling leads to the loss of a massive amount of scarce and valuable raw materials. Research has shown that precious metals such as neodymium for making magnets in motors, indium for making flat-panel TVs, and cobalt used in manufacturing batteries can be lost when e-wastes are mishandled.[175] Precious metals like cobalt and neodymium are challenging to extract from e-waste during recycling. For instance, only 30% of cobalt has been recovered even though technological advancement makes it possible to recover 95%.

Additionally, cobalt alone is very precious and in high demand for the manufacture of smartphones.[176] The value of these metals can only be realized with a proper understanding of the global e-waste dynamics. First, there must be an assessment of e-waste quantities. Achieving accurate monitoring and evaluation of e-waste quantities requires proper framework and methods of collecting and determining e-waste quantities and flows.

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[172] Baldé, C.P., Wang, F., Kuehr, R., Huisman, J.: *The Global E-waste Monitor – 2014: Quantities, Flows, and Resources*, (United Nations University, IAS – SCYCLE, Bonn, Germany, 2015) p. 50.
https://i.unu.edu/media/ias.unu.edu-en/news/7916/Global-E-waste-Monitor-2014-small.pdf
[173] *A New Circular Vision for Electronics: Time for A Global Reboot,*
(World Economic Forum; Platfotm for Accelerating the Circular Economy (PACE), 2019) p. 11.
http://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf
[174] USGS (2014). U.S. Geological Survey, Mineral Commodity Summaries, U.S. Geological Survey (USGS).
[175] *A New Circular Vision for Electronics: Time for A Global Reboot,*
(World Economic Forum; Platfotm for Accelerating the Circular Economy (PACE), 2019) p. 11.
http://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf
[176] Ibid.

4.2 Global E-Waste Quantities, Monitoring and Evaluation

Monitoring e-waste quantities, movement, and other aspects are essential for several reasons. First, e-waste monitoring is essential to track development in the sector and the related manufacturing, processing, and recycling industries.[177] As already highlighted above, the value of e-waste depends on many factors, including generation, consumption, and disposal of electronic and electrical equipment. Therefore, monitoring quantities at every point is an essential step in gauging the value of e-waste and tracking the development in the industry.[178]

Secondly, the evaluation of quantities helps in setting and monitoring targets. The management of e-waste is often done through combined legal and policy mechanisms. Some of the international legal instruments that will be discussed in Chapter 5 regulate the production and transboundary movement of e-waste.[179] Other sets of international legal instruments cap on the level of different found in e- hazardous chemicals wastes and even sets targets on the dates to end the production of such chemicals.[180] These targets can only be set where the quantities of e-waste are known, and the targets are monitored against the available data on e-waste. Lastly, the e-waste quantities are significant in identifying policy concerns.[181] This research aims to develop practical legal, regulatory, and policy mechanisms in the recycling of e-waste. However, such policies cannot be developed, rectified, or identified without first assessing the level of generation and

[177] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017) p. 24. https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

[178] Ibid.

[179] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (adopted 22 March 1989, entered into force 5 May 1992) 1673 UNTS 126. Available at: http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

[180] Stockholm Convention on Persistent Organic Pollutants (adopted 22 May 2001, entered into force 17 May 2004) 2256 UNTS 119. Available at: http://chm.pops.int/Portals/0/Repository/convention_text/UNEP-POPS-COP-CONVTEXT-FULL.English.PDF

[181] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017) p. 24. https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

discard of e-waste. Hence, this chapter demonstrates the dynamics of e-wastes from production, monitoring, and calculations

Although this chapter looks at the statistics at an international level, it fully acknowledges that businesses and households are the proper places to record statistics. Ordinarily, statistics are collected at the national or municipal level. However, it is equally important to collect the statistics at the international level. It is easier to organize the data according to each country and compare them at the international level. The data should then be updated, published, and interpreted to identify international trends and forecasts.[182] However, developing statistics at the international level has challenges due to the unavailability of official statistics. Notably, as of 2017, there were only 41 countries that collected official statistics on e-waste.[183]

Most countries have no national laws that govern e-waste operations, while others have the laws but lack frameworks for collecting any data on e-wastes. Even those countries with official statistics do not have regular and harmonized data save for Europe.[184] The gap, especially in countries without official statistics, creates a barrier to addressing the e-waste challenge. A 2017 report by the Global Monitor notes that proper data management can help minimize the generation of e-waste, mitigate unlawful dumping and emissions, enhance recycling, and create employment opportunities in the reuse, refurbishment, and recycling sectors.[185]

4.3 Measuring Global E-Waste Generation, Quantities and Flows

Another critical aspect in tracing and understanding e-wastes is the procedure for getting a uniform measuring tool that can be used globally. As already noted, the world experiences challenges in getting complete official national statistics on e-waste. The lack of official statistics

[182] Ibid.
[183] Baldé et al.: *The Global E-waste Monitor 2017*.
[184] Ibid.
[185] Ibid.

on the flows of e-waste is further compounded by the lack of harmonization of collection and calculation of the weight of e-waste.[186] Internationally, methods, models, and procedures have been developed to help in harmonizing the data on e-wastes. These frameworks ensure that essential features of the e-waste dynamics are captured. Generally, the calculations of e-wastes at the international level are generated from the empirical data, a model, and statistical routines. At times, international partners on e-waste work together to generate empirical data through questionnaires or using the statistics issued by the government.[187]

The most commonly used measurement system for e-waste statistics has been developed through the Partnership Measuring ICT for Development.[188] This framework was developed to cover the essential aspects of e-waste disposal scenarios worldwide and consistently measure the e-waste dynamics.[189] First, the framework starts by considering sales of electrical and electronic equipment. The first phase is often referred to as the market entry phase. The data at the market entry point may be available from statistics on sales obtained from a national e-waste registry for compliance with the Extended Producer Responsibility. Alternatively, the market entry data may be measured with a consumption method.[190] This research highlights the data at the market entry phase by considering sales data and the global consumer market size, as evident from the following section.

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[186] Baldé, C.P., Wang, F., Kuehr, R., Huisman, J.: *The Global E-waste Monitor – 2014: Quantities, Flows, and Resources*, (United Nations University, IAS – SCYCLE, Bonn, Germany, 2015). https://i.unu.edu/media/ias.unu.edu-en/news/7916/Global-E-waste-Monitor-2014-small.pdf

[187] Baldé et al.: *The Global E-waste Monitor 2017*.

[188] The Partnership for Measuring ICT for Development is a multi-stakeholder initiative that was launched in 2004 to improve the availability and quality of ICT data and indicators. It established a task group on e-waste statistics under the leading role of the UNU and garnered support from various international agencies such as ITU, UNEP-Secretariat of Basel Convention, Eurostat, and UNCTAD.

[189] Baldé et al.: *The Global E-waste Monitor 2014 & 2017*.

[190] Baldé et al.: *The Global E-waste Monitor 2017*.

The second phase after-sale is the product's "lifetime" or "residence time." This stage refers to when the equipment remains in the household or offices and is known as the stock phase. It includes the time when the equipment can be exchanged between households and businesses as second-hand goods within the country.[191] In ideal situations, the residence times of each product should be assessed empirically for every product. Data on the stock of electrical and electronic equipment (EEE) is determined through household and business surveys at a domestic level. However, in the absence of such surveys, the data may be calculated using the sales data and the equipment's time in the stock phase.[192]

The third phase under the framework considers the generation of e-waste. Generally, the product will be disposed of after a certain residence period, especially when it becomes obsolete to its final owner. The e-waste generation is domestic and does not involve either import or export of wastes, and is accumulatively accounted for annually. The e-waste generated can be collected using the official take-back system, mixed residual waste, collection outside formal take-back systems, and collection outside formal take-back systems.[193]

4.4 Calculating the Global E-waste Data at Domestic Level

Each report may develop the methodologies of calculating the statistics at each phase of handling electronics and e-waste. In 2014, for instance, the Global E-waste Monitor developed seven steps in generating their global data on e-waste.[194] First, the codes describing the electrical and electronic equipment were selected from the Harmonized Commodity Description and Coding System (HS). The step was followed by extracting the data for 175 countries using 260 HS codes from the UN Comtrade database between 1995 and 2012. Besides, the global trade statistical data

[191] Baldé et al.: *The Global E-waste Monitor 2014*.
[192] Baldé et al.: *The Global E-waste Monitor 2017*.
[193] Ibid.
[194] Baldé et al.: *The Global E-waste Monitor 2014*.

for European Union was obtained from Eurostat in the eight-digit combined nomenclature (CN) codes. The CN codes are similar to the HS codes used in other regions. However, the descriptions in CN codes are a bit detailed compared to HS. The Eurostat also contained domestic production data of European Union member states.[195]

The units obtained from the databases were then converted to weight using the average weight data per appliance type. Sales for 54 grouped product categories under the first group analyzed using the HS codes were calculated using the apparent consumption approach: Sales = Import – Export. Additionally, the sales for 28 EU members relying on the CN codes were calculated using the formula: Sales = Domestic Production + Import – Export.[196] A series of automated outlier analyses were then performed on the sales data to detect low or high values. For example, some countries lacked domestic production data despite the domestic production being relatively large. Other counties had high data with high values due to misreporting of codes or units. In case of extremely low or high data anomalies, the values were replaced with realistic sales figures from time series analysis of a country or comparable nations.[197] These steps were intended to harmonize the dataset with a similar scope and consistent sales for a country based on their trade statistics.

The e-waste per country was determined using the "Sales – Lifespan Distribution" method with empirical lifespan data. The report employed the Weibull distribution to obtain the lifespan data from the 28 EU member states.[198] Under the Weibull function, the lifetime of EEE assumes the parameters of scale and shape so that the profiles of the EEE will be based on those

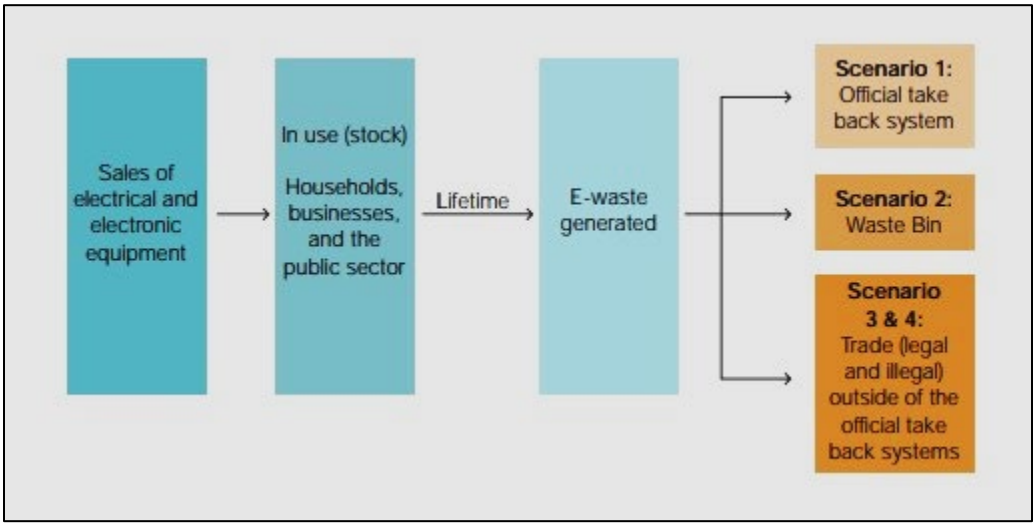
[195] Ibid.
[196] Ibid.
[197] Baldé et al.: *The Global E-waste Monitor 2014*.
[198] Baldé, C. P., R. Kuehr, K. Blumenthal, S. F. Gill, J. Huisman, M. Kern, P. Micheli and E. Magpantay (2015). *E-waste statistics: Guidelines on classifications, reporting and indicators*. Bonn, Germany, United Nations University, IAS - SCYCLE.

parameters.[199] The 2014 report worked with the closest real-life characteristics by fitting the scale parameter associated with the average life of EEE to actual data in the EU. Therefore, the lifetime profiles for each product were constructed by considering the average age of household EEE stocks and the average age of discarded e-waste, including the dormant time of electronic equipment on storage.[200]

4.5 Methods of E-waste Management and Collection

As noted above, e-waste management is the last phase in the electrical and electronic equipment life cycle. The four phases described include market entry, stock, e-waste generated, and waste management. Notably, during e-waste management, one considers the scenarios of collecting obsolete electrical and electronic equipment. The figure below shows the life cycle of EEE and the four possible scenarios of collecting e-waste.

Figure 4.2. Framework Measuring E-waste Flows



Source: Baldé et al.: *The Global E-waste Monitor 2014*[201]

[199] Baldé et al.: *The Global E-waste Monitor 2014*, p. 17.
[200] Ibid.
[201] Baldé, C.P., Wang, F., Kuehr, R., Huisman, J.: The global e-waste monitor – 2014, *Quantities, Flows, and Resources*, (United Nations University, IAS – SCYCLE, Bonn, Germany, 2015).
https://i.unu.edu/media/ias.unu.edu-en/news/7916/Global-E-waste-Monitor-2014-small.pdf

The first scenario is the 'Official Take-Back System,' often provided under national legislation providing e-wastes. The official take-back can be done by select organizations specializing in the collection of e-waste. Equally, producers can collect the e-wastes through the Extended Producer Responsibility (EPR) arrangement. The government may also engage in the official take-back of obsolete electronic equipment. The official collection often happens in three main points. The first point is via the retailers who collect the used electricals and electronic equipment. Local governments may also designate municipal collection points where electronic wastes may be discarded. Thirdly, there may be designated pick-up services that may go around the city collecting e-wastes.

After collecting e-waste from designated points, it is taken to a state-of-the-art treatment facility to recover valuable materials in an ecologically sound way. At this stage, the data on e-waste may be collected directly from the facility. Notably, such data collection may be necessitated by legislation that enables monitoring with recycling and collection targets. At the international level, data on the quantity of domestic e-waste collected and recycled are gathered from nations to assess the progress on e-waste management.[202]

The second scenario is the collection under the Mixed Residual Waste. This scenario is where the owners of the products dispose of their obsolete electronics alongside other household wastes into the standard dustbins. Most e-wastes disposed of in this scenario either end up in landfills or municipal solid waste incinerators with limited chances of separation before their final destination. Notably, incineration and landfilling lead to pollution and loss of resources, and inappropriate waste treatment techniques. For instance, landfilling causes toxins into the environment, while incineration leads to emissions into the air. Small equipment, small IT

[202] Baldé et al.: *The Global E-waste Monitor 2017*.

equipment, and lamps are often disposed of under the Mixed Residual Value in developed and developing countries.[203]

The last scenario is the collection outside the official take-back system and management of e-waste. Such a scenario differs in developed and developing countries. In most developed countries, there are formal waste management practices for municipal waste recycling. Individual waste dealers or companies collect e-waste and trade them using different channels. The traded e-wastes may end up in metal recycling, plastic recycling, or specialized e-waste recycling.

Additionally, other e-wastes may be exported to other countries for processing or other uses. There are also chances of informal collection in developed countries. In such instances, e-waste is often not treated in a specialized recycling facility for e-waste management. The informally collected e-waste from the developed world has a high likelihood of being shipped to developing countries. Examples of e-wastes commonly handled by informal collectors include temperature exchange equipment, large equipment, and IT products.

The 2017 Global E-waste Monitor noted that the developing countries experience a high demand for imported, cost-effective second-hand products and secondary materials, causing a surge in imported EEE. The second-hand imported goods and secondary materials add to the already collected domestically generated e-waste.[204] However, the treatment following informal collection is usually done in a hazardous manner to the environment. In some cases, the collected electronic equipment lacks reuse value and is mainly recycled through "backyard recycling" or substandard methods. Examples of outdated treatment methods applied for the EEE encompass open burning to extract metals, acid leaching for precious metals, unprotected melting of plastics, and direct discarding of hazardous residuals. One of the causes of such substandard treatment of

[203] Ibid.
[204] Baldé et al.: *The Global E-waste Monitor 2017*.

e-waste in developing countries is the lack of e-waste legislation. As already stated, e-waste legislation ensures that the treatment of e-wastes is done in an environmentally sound manner.

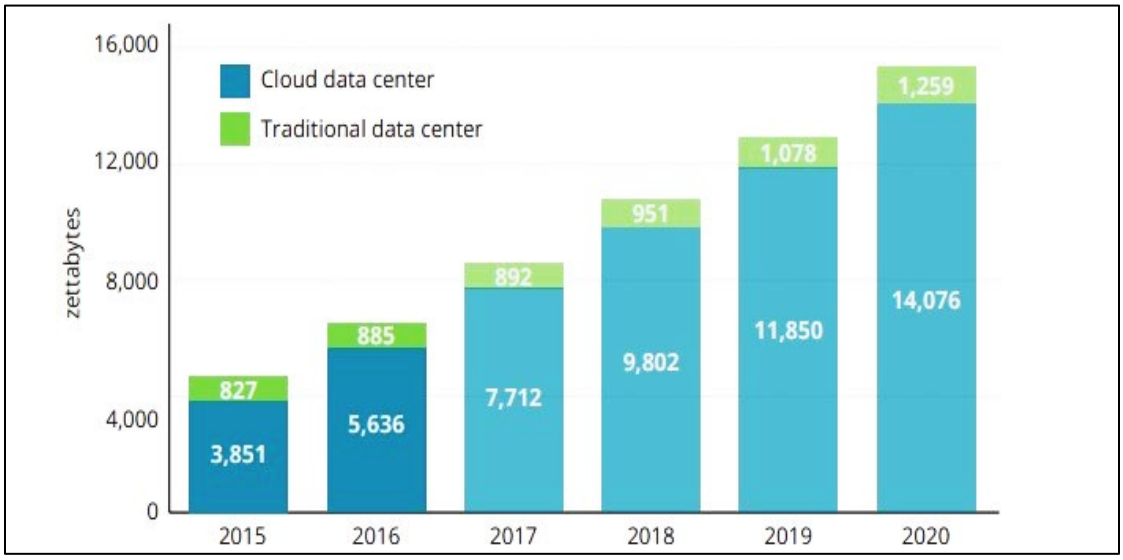
4.6 Global Consumer Electronics Market Size

The economic value of e-waste is also dependent on the consumption of e-wastes. More consumption of electronics means that more e-waste will be generated. Over the years, the consumption of electronics has steadily increased due to technological advancements. Equally, there has been a ready market for used electronic equipment in developing countries. The used electronics are affordable to most citizens for mobile money transfers and other e-commerce transactions. Thus, the increased financial inclusion in the developing world has created many opportunities for the consumption of affordable electronics to both middle-income and lower-income earners. Second-hand devices such as smartphones, tablets, cameras, laptops, and home appliances have second and third lives in the developing world before reaching their end-of-life stage. This consumer trend in the developing world points to the possibility of high e-waste volume for possible recycling.

According to Global E-Waste Monitor, 2017, there are 7.7 billion mobile-cellular subscriptions and 4.2 billion active mobile broadband subscriptions worldwide. The increased demand for smartphones worldwide stems from the fact that a mobile broadband signal covers over 80% of the world's population. Similarly, about 54% of households access the internet while 48% possess a computer. **Figure 4.2.** illustrates the increase in the use of the internet in terms of modern data technology. In terms of monetary value, the report noted that the value of global business-to-business (B2B) e-commerce was over US$22 trillion, and business-to-consumer (B2C) value was approximately US$3 trillion in 2015 alone. This report also found that people frequently changed their smartphones, laptops, PCs, routers, TV sets, and other devices because of the latest upgrades, higher speeds, and the latest technologies. Most devices were not replaced

because they were broken or obsolete thus outdated. In 2016, the consumer trend in the consumption of TVs was influenced by digital migration, where consumers switched from analog to digital TV broadcasting. Many TV sets were discarded merely for being outdated rather than being dysfunctional. The switchover led to the dumping of a voluminous number of Carbon-Ray-Tube TVs that may later become e-waste.

Figure 4.3. Global data center traffic in zettabytes



Source: Baldé et al.: *The Global E-waste Monitor 2017*[205]

The Zion Market Research placed the global consumer electronics market at approximately $1,172 billion in 2017.[206] The same report projected the global consumption rate to reach h $1.7 billion in 2024 based on a predicted growth rate of 6%. The rising consumption rate is attributable to several factors. First, the electronics market gained momentum after a slag period between 2011 and 2013 due to solid performance in India and China. Secondly, the availability of new products

[205] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017) p. 20. https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

[206]Zion Market Research, Global Consumer Electronics Market Will Reach USD 1,787 Billion, [Press Release] https://www.globenewswire.com/news-release/2018/06/29/1531798/0/en/Global-Consumer-Electronics-Market-Will-Reach-USD-1-787-Billion-by-2024-Zion-Market-Research.html

and concepts has fueled the growth of the global consumption rate of electronics. Thirdly, the adoption rate of smartphones and the advancement of technologies such as 3G and 4G have contributed to the rising global consumption of electronics.

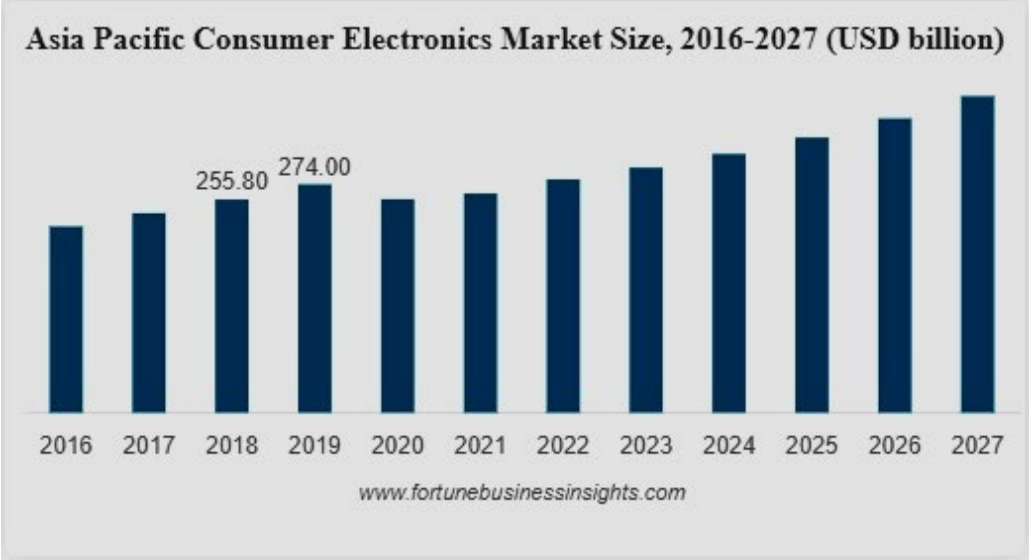
The Zion report also noted that electronics like washing appliances recorded significant growth worldwide because of rapid innovations and new development in technologies. Further, the consumer behavior was attributable to the industry's adoption of modern technology, where distributors and manufacturers availed the most modern appliances to consumers. The manufacturers influenced the consumer electronics market by producing front load fully automatic, top load semi-automatic, and fully automatic washing machines and dryers. Other factors such as e-commerce, retail chains, and direct selling increased product availability and boosted sales of the washing appliances.

The growth in consumption of electronics has been significant within the Asian Pacific region. For instance, Asian Pacific recorded a larger share in revenue generation in the global consumer electronics market. LG Electronics registered exponential growth in sales volume and profit since 2015. Notably, the filings at the Registrar of Companies placed the company sales at USD 1.936 billion in March 2015, signifying a growth rate of 12% as profit after tax rose by 20% to USD 113 million. By category, the sales rose by 12% in the home appliances sector, 12% in smartphones, and 11% in home entertainment. However, the statistics changed in 2020 where the percentage share of monitors in terms of total revenue increased to 23% in the second quarter (Q2) 2020 from 17% in the first quarter (Q1) 2020.[207] LG Electronics recorded increased revenues from notebook and tablets sales which rose from 20% in the first quarter of 2020 to 29% in the second

[207] *Consumer electronics market size, share, growth | Trends [2027]*. (2021, January). Fortune Business Insights™ | Global Market Research Report & Consulting. https://www.fortunebusinessinsights.com/consumer-electronics-market-104693

quarter. **Figure 4.4.** shows the growth in market size of electronics in the Asia Pacific, according to Fortune Business Insights.

Figure 4.4. Asia Pacific Consumer Electronics Market Size (2016 – 2020) & Projected Market Size (2021 – 2027)



Source: Fortune Business Insights, 2021.

Another report by the Japan Electronics and Information Technology Industries Association (JEITA) projected a 2% production growth in the global electronics and IT industries in 2020.[208] The value of electronics was expected to reach $2,972.7 billion in 2020. The trend partly resulted from the coronavirus pandemic, which caused demand for electronic devices to plummet. Nonetheless, the sales of other electronics such as computers rose as more people turned to telework. Concurrently, the demand for more semiconductors to beef up data centers faced with spiking telecommunications volume rose. Equally, more sophisticated data utilization required more solution services leading to a boost in electronics sales. The coronavirus pandemic has led

[208] Japan Electronics and Information Technology Industries Association (JEITA), *Production Forecasts for the Global Electronics and Information Technology Industries*, December 16, 2020. https://www.jeita.or.jp/english/press/2020/1216.pdf

to more widespread use of remote IT technologies, and the report projects a positive growth of 7% per year to $3,175.6 billion in 2021.[209]

4.7 Global Economic Value of E-Wastes

The economic value of electronic wastes can be summarized along two lines of the value of recycled metals and the number of jobs created in the formal and informal recycling industry. First, e-wastes contain valuable and rare earth metals.[210] The economic value of metals found in e-waste, including gold, silver, copper, platinum, and palladium, among others, is enormous. According to a Platform for Accelerating the Circular Economy (PACE) report, a tonne of smartphones contains 100 times more gold than a tonne of gold ore.[211] As illustrated in the table below, if most end-of-life phones were recycled, the world would be rich in gold. For instance, in 2017, 1.46 billion smartphones were sold, while in 2016 alone, 435,000 tonnes of phones were discarded. Assuming that each unit of smartphones contains electrical components with a retail price of $100.49, as suggested by some reports, it means that there is much money entering the market each year. If the raw materials from the smartphones can be recycled, they could be worth up to $11.5 billion. These figures point to the need for more recycling of e-waste that is often sitting in landfills and homes.

[209] Ibid.
[210] *A New Circular Vision for Electronics: Time for A Global Reboot,*
(World Economic Forum; Platfotm for Accelerating the Circular Economy (PACE), 2019) p. 11.
http://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf
[211] Ibid.

Table 4.1: Potential value of raw materials in e-waste in 2016

Material	kilotons (kt)	Million €
Fe	16,283	3,582
Cu	2,164	9,524
Al	2,472	3,585
Ag	1.6	884
Au	0.5	18,840
Pd	0.2	3,369
Plastics	12,230	15,043

Source: Baldé et al.: *The Global E-waste Monitor 2017*[212]

The second economic value of e-wastes is the number of jobs created in the recycling industry, whether formal or informal. In 2013, the International Labor Organization (ILO) reported that about 19 to 24 million women and men were employed in the solid waste management and recycling industry worldwide. Four million out of the 19 to 24 million worked in the formal waste and recycling sector.[213] The ILO had further reported estimated regional figures in 2019.[214] About 690,000 women and men were estimated to be working as collectors or recyclers in 2007 in China, according to a 2013 report by UNU/StEP Initiative.[215] Moreover, ILO reported in 2014 that about

[212] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017) p. 54. https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

[213] ILO: *Sustainable development, decent work and green jobs*, Report V, International Labour Conference, 102nd Session, Geneva, 2013. http://www.ilo.ch/wcmsp5/groups/public/---ed_norm/---relconf/documents/meetingdocument/wcms_207370.pdf

[214] ILO: *Decent work in the management of electrical and electronic waste (e-waste)*, GDFEEW/2019, Issues paper for the Global Dialogue Forum on Decent Work in the Management of Electrical and Electronic Waste (E-waste) (Geneva, 9–11 April 2019). https://www.ilo.org/sector/activities/sectoral-meetings/WCMS_673662/lang--en/index.htm

[215] F. Wang et al.: *E-waste in China: A Country Report* (Bonn, UNU/StEP Initiative, 2013). https://collections.unu.edu/eserv/UNU:1624/ewaste-in-china.pdf

5,000 to 8,000 people worked as e-waste collectors in Serbia.[216] Another report by ILO in 2016 concerning Argentina noted that about 34,000 people were estimated to be working in the e-waste value chain in 2016.[217] In Africa, the labor force from e-waste recycling has been estimated to have reached 5,324 workers in South Africa. The e-waste workers are employed in the 62 member companies of the e-Waste Association of South Africa.[218] Additionally, it is estimated that about 100,000 people work in the e-waste economy in Nigeria.[219] Table 4.1. below indicates the available national and municipal employment estimates across Waste Electrical and Electronic Equipment (WEEE) treatment sectors.

Table 4.2. Available national and municipal estimates of employment across WEEE treatment sectors.

Country/ Municipality	Estimated No. of Workers	Description of work category
China	690,000	Collectors or recyclers
Serbia	5,000 -8000	Collectors
Argentina	34,000	In the e-waste value chain
Nigeria	100,000	In the e-waste economy
South Africa	5, 324 in 62 companies	E-Waste Association of South Africa
Dhaka, Bangladesh	60,000	In e-waste
New Delhi, India	10,000 – 25,000	Informal e-waste workers

[216] ILO: *Tackling informality in e-waste management: The potential of cooperative enterprises* (Geneva, 2014). https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_315228.pdf
[217] ILO: *Sustainable development, decent work and green jobs*, Report V, International Labour Conference, 102nd Session, Geneva, 2013. http://www.ilo.ch/wcmsp5/groups/public/---ed_norm/---relconf/documents/meetingdocument/wcms_207370.pdf
[218] E-waste Association of South Africa (eWASA): Assessment of the job creation potential in e-waste through sustainable enterprise development, with a special focus on e-waste in the automotive industry (2014, unpublished); McMahon, Kathleen, Yvonne Ryan-Fogarty, and Colin Fitzpatrick. "Estimating job creation potential of compliant WEEE pre-treatment in Ireland." *Resources, Conservation and Recycling* 166 (2021): 105230. https://reader.elsevier.com/reader/sd/pii/S0921344920305450?token=B633A4784CC4ECB9704E66DE084DA022BF63A444BCBEC7859671C0FC0D147DC1576E31301E6517BCDBE594EE32DADBDC&originRegion=eu-west-1&originCreation=20210712125908
[219] Olakitan Ogungbuyi, Innocent Chidi Nnorom, Oladele Osibanjo & Mathias Schluep.: E-waste country assessment Nigeria (Secretariat of the Basel Convention, 2012). http://www.basel.int/Portals/4/Basel%20Convention/docs/eWaste/EwasteAfrica_Nigeria-Assessment.pdf

Source: Kathleen M., Ryan-Fogarty Y., and Fitzpatrick C., 2021.[220]

4.8 Regional Trends in E-Waste Generation and Recycling

The global estimate of e-waste produced in 2014 was 41.8 Mt. In terms of e-waste legislation, and national e-waste laws covered about 4 billion persons. Even though the legislation does not guarantee enforcement, it signifies a sense of proper management. Notably, national laws are essential to ensure proper management of the e-waste dynamics from production, disposal up to recycling. Globally, around 6.5 Mt of e-waste was reported as formally treated by national take-back systems in 2014. Further, 0.7 Mt of e-waste was discarded into the waste bin in the 28 EU Member States in 2014 while other regions remained unaccounted for in that year. The report also shows that the composition of global e-waste in 2014 included 1.0 Mt lamps, 3.0 Mt of Small IT, 6.3 Mt of screens and monitors, 7.0 Mt of temperature exchange equipment (cooling and freezing equipment), 11.8 Mt of large equipment, and 12.8 Mt of small equipment. The report forecasted an annual growth rate of 4 to 5 percent, as illustrated by the table below. With this annual growth rate, e-waste was expected to grow to 49.8 Mt in 2018.

[220] McMahon, Kathleen, Yvonne Ryan-Fogarty, and Colin Fitzpatrick. "Estimating job creation potential of compliant WEEE pre-treatment in Ireland." *Resources, Conservation and Recycling* 166 (2021): 105230. https://reader.elsevier.com/reader/sd/pii/S0921344920305450?token=B633A4784CC4ECB9704E66DE084DA022BF63A444BCBEC7859671C0FC0D147DC1576E31301E6517BCDBE594EE32DADBDC&originRegion=eu-west-1&originCreation=20210712125908

Table 4.3: Global Quality of E-Waste Generated in 2014 & Projected Growth (2015-'18)

GLOBAL QUANTITY OF E-WASTE GENERATED			
Year	**E-waste generated (Mt)**	**Population (billion)**	**E-waste generated (kg/inh.)**
2010	33.8	6.8	5.0
2011	35.8	6.9	5.2
2012	37.8	6.9	5.4
2013	39.8	7.0	5.7
2014	41.8	7.1	5.9
2015	*43.8*	*7.2*	*6.1*
2016	*45.7*	*7.3*	*6.3*
2017	*47.8*	*7.4*	*6.5*
2018	*49.8*	*7.4*	*6.7*

Data 2015 onwards are forecasts

Source: Baldé et al.: *The Global E-waste Monitor 2014*[221]

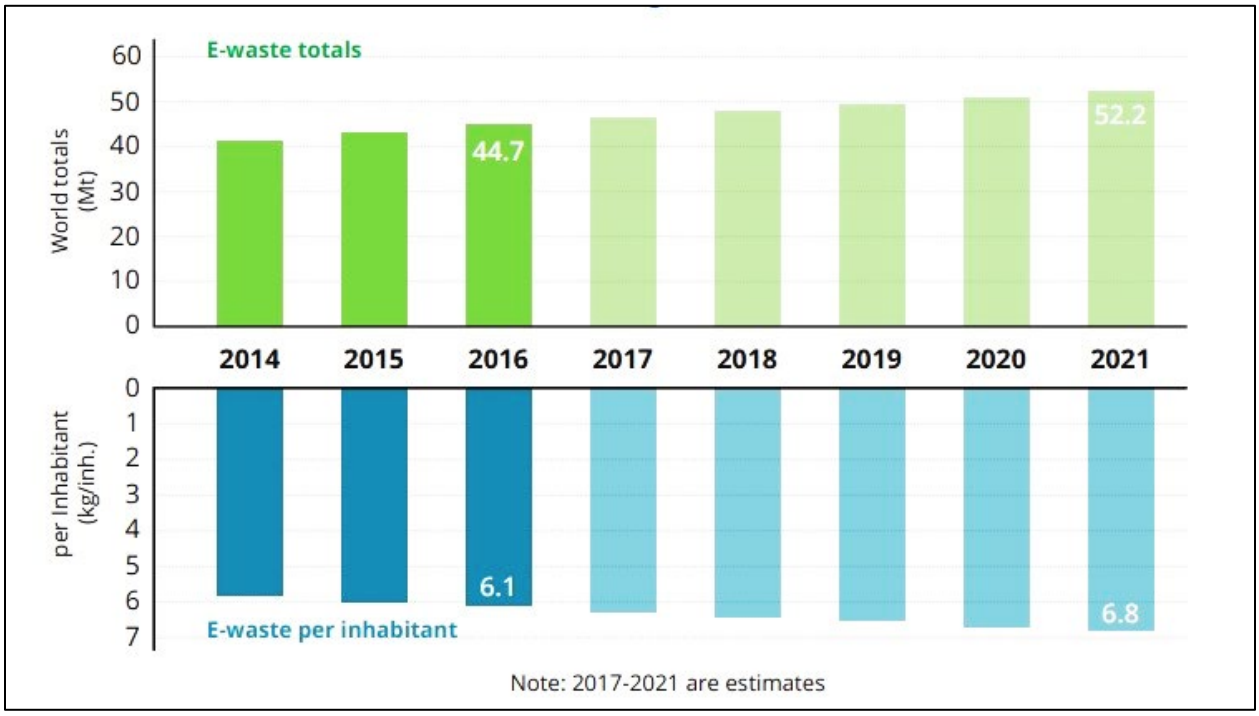
Regionally, Asia took the lead in e-waste generation in 2014 by accounting for 16 Mt, which translates to 3.7 kg for each inhabitant. However, the highest e-waste quantity generated per inhabitant in 2014 stood at 15.6 kg/inh and came from Europe. Europe, including Russia, generated 11.6 Mt. Oceania generated the lowest e-waste quantity amounting to 0.6 Mt even though its per inhabitant amount was nearly as high as Europe's and stood at 15.2 kg/inh. Africa generated a total of 1.9 Mt of e-waste, translating to a per inhabitant rate of 1.7 kg/inh. Lastly, the Americas generated 11.7 Mt of e-waste, comprising 7.9 Mt for North America, 1.1 Mt for Central America, and 2.7 Mt for South America), which represented 12.2 kg/inh.

These figures slightly changed in 2016 when another report on the global e-waste status was published. The global quantity of e-waste generation in 2016 was around 44.7 million metric tonnes (Mt), or 6.1 kg per inhabitant. The quantity fell slightly below the amount predicted in the 2014 report, which placed the forecast at 45.7 Mt, as shown in Figure 4.5 above. The 2017 report projected an annual growth rate of 3 to 4% instead of 4 to 5 percent projected in 2014. At the rate

[221] Baldé, C.P., Wang, F., Kuehr, R., Huisman, J.: The Global E-waste Monitor – 2014, *Quantities, Flows, and Resources*, (United Nations University, IAS – SCYCLE, Bonn, Germany, 2015). https://i.unu.edu/media/ias.unu.edu-en/news/7916/Global-E-waste-Monitor-2014-small.pdf

of 3 to 4%, the world e-waste generation by 2017 was expected to exceed 46 Mt and grow to 52.2 Mt in 2021, as illustrated by the figure below.

Figure 4.6: Global E-waste Generated in 2016 with Predictions (2017- 2021)



Source: Baldé et al.: *The Global E-waste Monitor 2017*[222]

Although only 4 billion people were covered by e-waste legislation in 2014, this figure rose steadily to 4.8 billion by January 2017. Thus, 66% of the world population is covered in the 67 countries with national e-waste legislation compared to 44% in 2014. Notably, six additional countries passed e-waste legislation between 2014 and January 2017, making the total number of countries rise from 61 in 2014 to 67 in January 2017. Further, the amount of e-waste collected and recycled by an official take-back system rose to 8.9 Mt in 2016, while a total of 1.7 Mt of e-waste reportedly ended up in waste bins from the wealthiest countries in the world. The 2017 report

[222] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017) p. 38. https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

by the Global E-waste monitor noted that approximately 34.1 Mt of e-waste generated worldwide in 2016 was untraced and unreported. Much of the e-waste could be attributed to waste that is managed outside the official take-back system.

Similar to the 2014 report, Asia equally led other regions in the generation of e-waste in 2016. Asia accounted for approximately 18.2 Mt of e-waste generated, which translates to 4.2 kg per inhabitant. Out of the 18.2 Mt of e-waste generated, only 2.7 Mt were documented to be collected and recycled. Oceania was reported to have generated the highest quantity for each inhabitant, amounting to 17.3 Kg/inh. Oceania also maintained its record for generating the lowest quantity of e-waste in the world in 2016 at 0.7 Mt. However, only 43 kilotons (kt) of its e-waste was documented to be collected and recycled, which constituted 6% of the total e-waste generated in Oceania. The e-waste per inhabitant generated in Europe, including Russia, amounted to 16.6 Kg/inh. The whole amount of e-waste generated in Europe in 2016 was 12.3 Mt, but only around 4.3 Mt of e-waste was collected to be recycled.

Notably, Europe had the highest regional collection rate of 35%. Africa recorded the lowest amount of e-waste per inhabitant, standing at 1.9 kg/inh and generated a total of 2.2 Mt of e-waste. Recycling of e-waste was equally low in Africa, with data showing that only 4 kt were documented as collected and recycled, accounting for less than 1%. Lastly, the Americas generated 11.3 Mt of e-waste in 2016 with a per capita rate of 11.6 kg/inh. North America generated 7 Mt, followed by 3 Mt from South America and 1.2 Mt from Central America. Out of the total wastes generated in the Americas, approximately 1.9 Mt of e-waste documented was collected and recycled. As illustrated in the table below, there is a considerable difference between e-waste generated in developed and developing countries. According to the 2017 Global E-waste Monitor, the

wealthiest country in the world in 2016 generated an average of 19.6 kg/inh, whereas the poorest generated only 0.6 kg/inh.

Table 4.4: E-waste Generation and Collection per Continent 2016

Indicator	Africa	Americas	Asia	Europe	Oceania
Countries in region	53	35	49	40	13
Population in region (millions)	1,174	977	4,364	738	39
WG (kg/inh)	1.9	11.6	4.2	16.6	17.3
Indication WG (Mt)	2.2	11.3	18.2	12.3	0.7
Documented to be collected and recycled (Mt)	0.004	1.9	2.7	4.3	0.04
Collection Rate (in region)	0%	17%	15%	35%	6%

Source: Baldé et al.: *The Global E-waste Monitor 2017*[223]

Conclusion

This chapter dealt with the global dynamics of e-waste and e-waste flows. It demonstrated the steps that are necessary to turn waste into an economically viable recycling industry. Before estimating the value of the raw materials in e-waste, trends in e-waste generation must be monitored. The monitoring spans from the market entry phase to the discarding phase. One must equally harmonize the data generated at each phase and calculate the weight of the generated waste through a universally accepted framework. This chapter estimated the amount of e-waste generated globally using 2014, 2017, and 2020 Global E-waste Monitor reports. The chapter also looked at the market size for electronics from different sources before concluding with the value of most metals extracted from e-waste. During the discussions under this chapter, the role played by

[223] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017) p. 41. https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

national legislation remained recurrent. Europe and the developed world had better statistics, collection, and waste management frameworks due to national e-waste legislation. Notably, Europe had the highest level of e-waste generation per inh and e-waste recycling. However, Africa had the lowest e-waste generation, and recycling remained low. The analysis of global e-waste generation and recycling trends discussed in this chapter is critical in understanding the level of e-waste worldwide. As this study focuses on the GCC e-waste management to achieve an e-waste circular economy, the global data is essential in understanding the possible e-waste trends in the GCC.

The next chapter will discuss international treaties and conventions that affect the generation, transboundary movement, and disposal of electronic wastes and equipment. The chapter will discuss the international conventions related to the Basel Convention, Stockholm Convention, Minamata Convention, Rotterdam Convention, and the Montreal Protocol. Discussing the treaties will offer insights into how the GCC can implement laws towards ensuring efficient management of e-waste to limit their damage to the environment and human population within and across the geographical boundaries.

CHAPTER 5

INTERNATIONAL TREATIES ON ELECTRICAL AND ELECTRONIC WASTE

5.0 Introduction

The regulatory framework for recycling e-waste at the national and regional levels is heavily reliant on the international commitments of states. In most instances, states are parties to international and regional conventions regulating the trade in hazardous chemicals, electrical and electronic equipment, and hazardous wastes. This chapter discusses the international, regional, and multinational treaties where the GCC member states are parties and other comparative regional treaties. The first section discusses international conventions such as the Basel Convention, 1989;[224] Stockholm Convention, 2001;[225] Minamata Convention, 2013;[226] Rotterdam Convention, 1998;[227] and the Montreal Protocol, 1987.[228] The second section discusses regional treaties that regulate trade in hazardous chemicals and wastes. Treaties and directives from Africa, European Union, and South Pacific are discussed, including the Bamako Convention, 1998;[229] Waste Shipment Regulation (EC) Nº 1013/2006;[230] Restriction of Hazardous Substances in Electrical and

[224] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (adopted 22 March 1989, entered into force 5 May 1992) 1673 UNTS 126. Available at: http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

[225] Stockholm Convention on Persistent Organic Pollutants (adopted 22 May 2001, entered into force 17 May 2004) 2256 UNTS 119. Available at: http://chm.pops.int/Portals/0/Repository/convention_text/UNEP-POPS-COP-CONVTEXT-FULL.English.PDF

[226] Minamata Convention on Mercury (adopted 9 October 2013, entered into force 18 May 2017) Available at: http://www.mercuryconvention.org/Portals/11/documents/conventionText/Minamata%20Convention%20on%20Mercury_e.pdf

[227] Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (adopted 10 September 1998, entered into force 24 February 2004) Available at: http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx

[228] Montreal Protocol on Substances That Deplete the Ozone Layer (adopted 16 September 1987, entered into force 1 January 1989) Available at: https://treaties.un.org/doc/Treaties/1989/01/19890101%2003-25%20AM/Ch_XXVII_02_ap.pdf

[229] Bamako Convention on the ban on the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa Layer (adopted 30 January 1991, entered into force 22 April 1998) Available at: https://au.int/en/treaties/bamako-convention-ban-import-africa-and-control-transboundary-movement-and-management

[230] European Union, *Regulation (EC) No. 1013/2006 of the European Parliament and of the Council on shipments of waste*. Available at: http://extwprlegs1.fao.org/docs/pdf/eur65175.pdf

Electronic Equipment (RoHS) Directive, 2011;[231] Waste from Electrical and Electronic Equipment (WEEE) Directive, 2012;[232] Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) Regulation, 2006,[233] and the Waigani Convention, 1995.[234]

Generally, this chapter builds on the principles and standards of e-waste management as discussed in Chapter 3 of this research. In Chapter 3, principles such as environmentally sound management (ESM) of wastes, prevention, precautionary, prior notification, and proximity principles were discussed. Under this chapter, more emphasis is added to these principles based on the conventional obligation for states. The Basel Convention remains the most prominent treaty in this chapter. The convention regulates the trade of hazardous wastes and clarifies the types of wastes, including waste electrical and electronic equipment (WEEE). The discussion under the Basel Convention focuses on e-waste regulation and whether the convention allows for the recycling of e-waste in an environmentally sound manner within the GCC member states. Therefore, more guidelines issued by the Secretariat and the Conference of Parties (CoP) are

[231] European Union, *Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment OJ L 174 of 1 July 2011*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011L0065

[232] European Union, *Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02012L0019-20180704

[233] European Union, *Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) OJ L 396, 30.12.2006, p. 1–849*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R1907&from=EN

[234] Convention to Ban the importation into Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement of Hazardous wastes within the South Pacific Region (adopted 16 September 1995, entered into force 21 October 2001) Available at: http://macbio-pacific.info/wp-content/uploads/2017/08/Waigani-Convention.pdf

discussed, particularly the guidelines on recycling end-of-use mobile phones[235] and end-of-use computers.[236]

The remaining conventions, such as the Stockholm, Rotterdam, Minamata, and Montreal Protocol, are specific to various chemicals. The conventions are relevant to the discussion of e-wastes since they regulate some chemicals and substances that are either used in the manufacturing or recycling of electronic and electrical equipment, including mobile phones, computers, and refrigerators. The Stockholm Convention, for instance, regulates persistent organic pollutants (POPs) present in the plastic component of electrical and electronic equipment. Secondly, the Rotterdam Convention underpins the principle of prior informed consent in the regulation of hazardous chemicals. Similarly, the Minamata Convention espouses the ESM safeguards on human health and the environment where mercury is used to extract metals and manufacture electrical and electronic equipment. All the conventions and directives discussed under this chapter highlight the need for environmentally sound management of the chemicals they regulate, which form part of electrical and electronic equipment.

5.1 Basel Convention

The Basel Convention is a widely accepted environmental law with 188 state parties and 53 signatories.[237] Figure 5.1. below indicates the distribution of parties to the convention across the globe, and Figure 5.1 shows the convention's ratification within the GCC. The Basel

[235] Basel Convention Mobile Phone Partnership Initiative (MPPI), 2009e. *Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones*. Revised and approved text, 25 March 2009. Available from: http://basel.int/Implementation/TechnicalAssistance/Partnerships/MPPI/MPPIGuidelinesandGlossaryofTerms/tabid/3251/Default.aspx

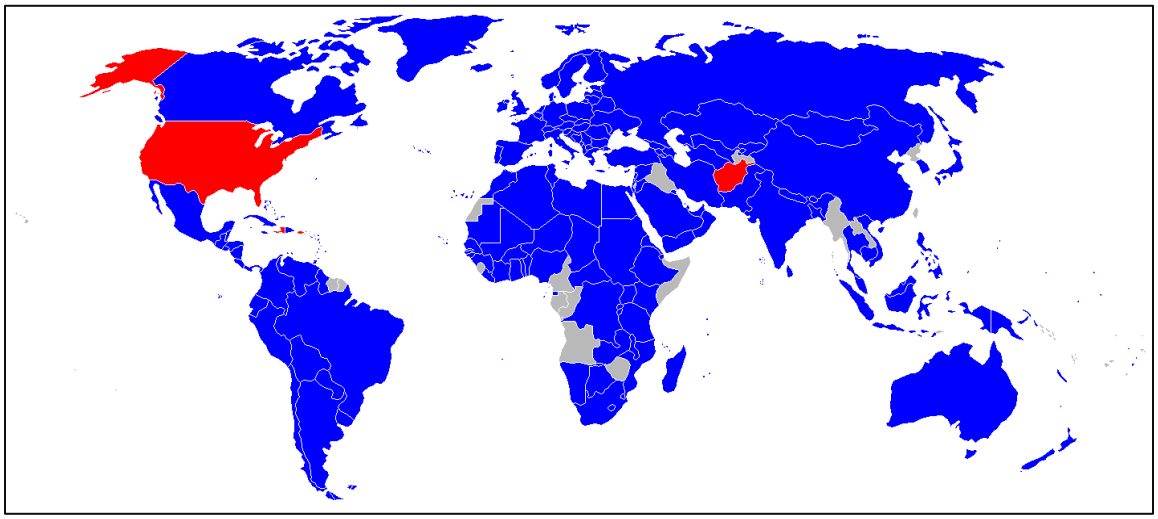
[236] Basel Convention Partnership on Action for Computing Equipment (PACE), 20112013b. *Guideline on Environmentally Sound Material Recovery and Recycling of End-of-Life Computing Equipment*. Revised in 10 May 2013. Available from: http://www.basel.int/Implementation/TechnicalAssistance/Partnerships/PACE/PACEGuidelines,ManualandReports/tabid/3247/Default.aspx

[237] Basel.int. 2021. *Parties to the Basel Convention*. [online] Available at: <http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx> [Accessed 8 May 2021].

Convention originated due to an international effort to address dangerous waste disposal witnessed in the 1980s that targeted the global south as disposal sites for harmful wastes.[238] The convention was adopted in 1989 and entered into force in 1992 under Article 26 with later addendums in 2006 (Nairobi Declaration) and 2011 (Cartagena Decisions).[239] Article 26 requires fifteen instruments of ratification, acceptance, approval, or accession before the convention could enter into force. The convention was to regulate the transboundary movement of hazardous wastes to preserve human health and the environment.[240] Transboundary movement as envisaged under the convention involves transporting waste wastes considered hazardous across international boundaries, especially into the territories of other states or regions considered to be beyond the territorial sovereignty of any state. The Basel Convention thus provides the most significant policy and regulatory framework on the transboundary movement of e-waste.[241]

[238] Valin, D., 1995. The Basel Convention on the Control of Transboundary Movements of Hazardous Waste and Their Disposal: Should the United States Ratify the Accord? *Indiana International & Comparative Law Review*, [online] 6(1), pp.267-288. Available at: <https://mckinneylaw.iu.edu/iiclr/pdf/vol6p267.pdf>.
[239] Djahane Salehabadi 'Transboundary Movements of Discarded Electrical and Electronic Equipment' *Solving the E-waste Problem (StEP) Initiative Green Paper Series*, 25 March 2013 at 9, available at http://www.step-initiative.org/index.php/Publications.html, Accessed on 08 May 2021.
[240] Ogunseitan, O., 2013. The Basel Convention and e-waste: translation of scientific uncertainty to protective policy. *The Lancet Global Health*, 1(6), pp. e313-e314.
[241] *id*.

Figure 5.1: Basel Convention Signatories. Blue: Signed and ratified; Red: Signed, but not ratified; Grey: Not a signatory. Source: (Wikimedia Commons, 2021)[242]



The regulatory framework of the convention provides for the definition of hazardous wastes, transboundary movement of such wastes, and how state parties must manage such wastes. Article 2 defines wastes as substances and objects that have either been disposed of or intended for disposal.[243] In other words, wastes are anything that has reached its end-use cycle. The convention also allows state parties to define what each individual state may consider as waste through their national laws.[244] Under Article 1, the convention categorizes some wastes listed in Annex I as hazardous.

Similarly, the domestic laws of member states may classify other wastes as hazardous. However, the classification must be deposited with the Secretariat within six months of ratifying the convention.[245] Moreover, the convention aims to minimize wastes and ensure environmentally

[242] Commons.wikimedia.org. 2021. *File:Basel Convention signatories.PNG - Wikimedia Commons*. [online] Available at: <https://commons.wikimedia.org/wiki/File:Basel_Convention_signatories.PNG> [Accessed 8 May 2021].
[243] Basel Convention, Art. 2.
[244] Basel Convention, Art. 3(1).
[245] Id.

sound management and transboundary movement of wastes. These three areas form the core vision of the convention that helps protect human health and the environment.[246]

Table 5.1: Status of Ratification of Basel Convention within the Gulf Cooperation Council (Basel Convention, Status of Ratifications, 2021)[247]

Participant	Signature, Succession to Signature (d)	Ratification, Acceptance (A), Approval (AA), Accession (a)	Entry into force
Bahrain	22/03/1989	15/10/1992	13/01/1993
Kuwait	22/03/1989	11/10/1993	09/01/1994
Oman		08/02/1995 (a)	09/05/1995
Qatar		09/08/1995 (a)	07/11/1995
Saudi Arabia	22/03/1989	07/03/1990	05/05/1992
United Arab Emirates	22/03/1989	17/11/1992	15/02/1993

Notably, the Basel Convention includes e-waste among the wastes that fall under its scope of wastes. In 1998, the fourth meeting of the conference of parties passed Decision IV/9, which added Annex VIII to the convention. Annex VIII lists e-wastes as hazardous based on entry A1180. Besides, non-hazardous e-wastes are classified under entry B1110.[248] This classification is essential in the discussions of this paper because not all electrical and electronic wastes are hazardous, while some equipment contains hazardous and non-hazardous components. Thus, the management of such equipment is essential, especially in realizing the economic value of the materials used in an environmentally sound manner.

[246] Alan Andrews, 'Beyond the Ban – can the Basel Convention adequately Safeguard the Interests of the World's Poor in the International Trade of Hazardous Waste?', 5/2 *Law, Environment and Development Journal* (2009), p. 167, available at http://www.lead-journal.org/content/09167.pdf
[247] http://www.basel.int/?tabid=4499
[248] Jonathan Kreuger, 'The Basel Convention and the International Trade in Hazardous Wastes' (2001) in Olav Scrhram Stokke and Oystein B Thommessen (eds.) (2001/2002) 43 *Yearbook of International Cooperation on Environment and Development* 45.

Further, Annex VIII classifies wastes as hazardous based on the definition of Article 1 paragraph 1 (a) of the convention. The Annex includes waste electrical and electronic assemblies or scrap containing accumulators and other batteries, mercury-switches, glass from cathode-ray tubes, and other activated glass and PCB capacitors. Equally, all other similar materials contaminated with elements such as cadmium, mercury, lead, and polychlorinated biphenyl are classified as hazardous, especially when they possess any of the characteristics listed in Annex III. Under Annex III, waste materials are considered hazardous where they are explosive, corrosive, infectious, flammable, liable to spontaneous combustion, and oxidizing.[249] Table 5.2 illustrates the entry of hazardous e-waste under the Basel Convention.

Annex IX further classifies wastes that are not covered under Article 1, paragraph (a). As already stated, Article 1 paragraph (a) deals with hazardous wastes; hence Annex IX involves wastes other than those under the hazardous category.[250] As a result, Annex IX deals with the non-hazardous wastes category. Annex IX provides that some e-wastes may be considered non-hazardous if not contaminated with elements that render them hazardous, as already discussed under entry A1180 above. Thus, electrical and electronic assemblies consisting only of metals or alloys, waste electrical and electronic assemblies or scrap (including printed circuit boards) not containing components such as accumulators and other batteries included on list A, and electrical and electronic assemblies intended to be reused are classified as non-hazardous under the convention.[251] Table 5.3. illustrates the entry of non-hazardous e-waste under the Basel Convention.

Table 5.2: A1 Metal and Metal-Bearing Wastes (Extract of Annex VIII, Basel Convention)

[249] Okukpon, Irekpitan. "Towards the sustainable management of electronic waste in Nigeria: South Africa as a model." (2015) p. 91.
[250] Id.
[251] Id.

A1180	Waste electrical and electronic assemblies or scrap9 containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB capacitors, or contaminated with Annex I constituents (e.g., cadmium, mercury, lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (note the related entry on list B B1110)[258]

Table 5.3: B1 Metal and Metal-Bearing Wastes (Extract of Annex IX, Basel Convention)

B1110	Electrical and electronic assemblies: • Electronic assemblies consisting only of metals or alloys • Waste electrical and electronic assemblies or scrap19 (including printed circuit boards) not containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB capacitors, or not contaminated with Annex I constituents (e.g., cadmium, mercury, lead, polychlorinated biphenyl) or from which these have been removed, to an extent that they do not possess any of the characteristics contained in Annex III (note the related entry on list A A1180) • Electrical and electronic assemblies (including printed circuit boards, electronic components and wires) destined for direct reuse,[258] and not for recycling or final disposal[259]

5.1.1 Minimization of the Generation of Hazardous Waste

The Basel Convention aims to preserve human health and protect the environment by limiting waste generation from a country where the waste originates.[252] There are no special e-waste minimization provisions other than the general requirements for minimizing all hazardous wastes. Under Article 4(2) of the Convention, parties bear the responsibility to limit the generation of hazardous wastes. The convention requires parties to consider the social, technological, and economic aspects of hazardous waste generation in ensuring that the generation of wastes within the territory of a party is kept to a minimum. This paragraph in the convention does not bar the production of hazardous waste but seeks to ensure that parties generate them using advanced

[252] Ogunseitan, O., 2013. The Basel Convention and e-waste: translation of scientific uncertainty to protective policy. *The Lancet Global Health*, 1(6), pp. e313-e314.

technologies that minimize the release of wastes. The provision equally strikes a balance between the economic value that accompanies waste generation and the social effects on human health and the environment.[253]

Secondly, under Article 4(2), parties are obliged to establish proper disposal facilities to ensure that the wastes are managed in an environmentally sound manner. Incidentally, such disposal facilities must be adequate and located as close to the point of generation as possible. This provision on locating the disposal facilities within the territory of a party generating the waste is called the proximity principle.[254] Much about the principle has been discussed in the earlier chapters of this research (see Chapter 3). Moreover, this provision can be seen as barring the transportation of hazardous wastes over far-off areas for disposal. Developed countries with advanced technologies to generate wastes must equally create environmentally sound waste disposal facilities within their territories. No wastes should thus be shipped from developed countries to the developing world if the wastes cannot be disposed of in an environmentally sound manner in the developing countries.[255]

The convention also provides for the minimization of pollution in the handling of hazardous wastes. The management of wastes must also happen with two goals. First, the management must factor in steps to prevent pollution from occurring.[256] This provision captures the prevention principle in environmental management discussed in Chapter 3 of this research. Secondly, the management of wastes should consider steps that minimize the consequences of

[253] Lipman Z. 'Transboundary movement of hazardous waste: environmental justice issues for developing countries' 1999 *Acta Juridica* 266 at 272.
[254] Okukpon, Irekpitan. "Towards the sustainable management of electronic waste in Nigeria: South Africa as a model." (2015) p. 91.
[255] Agbor, Avitus A. "The Ineffectiveness and Inadequacies of International Instruments in Combatting and Ending the Transboundary Movement of Hazardous Wastes and Environmental Degradation in Africa." *African Journal of Legal Studies*, vol. 9, no. 4, 2016, pp. 235-267.
[256] Basel Convention, Art. 4(2) (c).

pollution that arise from the pollution caused by the management of hazardous wastes.[257] However, the convention does not provide details of the minimum steps needed to limit the consequential effects of pollution on human health and the environment and whether compensation for the damage caused would minimize pollution. Nonetheless, minimization of hazardous waste as discussed in the convention is understood as part of environmentally sound management (ESM) of the wastes. ESM involves taking all reasonable steps to ensure that hazardous wastes or other wastes are managed to protect human health and the environment against the adverse effects of such wastes.[258]

The convention provides for the minimization of the transboundary movement of hazardous wastes. Parties are obliged to reduce transporting hazardous wastes to other territories.[259] Additionally, reducing the transboundary movement of wastes should conform to the environmentally sound and efficient management of the transported wastes. This provision equally reiterates the need to protect the environment from adverse effects which may result from the transboundary movement of hazardous wastes.

5.1.2 Transboundary Movement of Wastes

The Basel Convention prohibits transboundary movement of hazardous wastes unless it is consented to by the state of import and transit. Additionally, the convention only permits transboundary movement of hazardous wastes where such movement is to be done in an environmentally sound and effective manner.[260] Parties generally must prohibit the import of hazardous wastes into their territories.[261] Thus, African countries have passed the Bamako

[257] Id.
[258] Alan Andrews, 'Beyond the Ban – can the Basel Convention adequately Safeguard the Interests of the World's Poor in the International Trade of Hazardous Waste?', 5/2 *Law, Environment and Development Journal* (2009), p. 170.
[259] Basel Convention, Art. 4(2) (d).
[260] Basel Convention, Art. 4(2) (d) & (8).
[261] Id. Art. 4(2) (11).

Convention that bans import hazardous into the continent.[262] The Basel Convention equally puts some obligations on the developed countries to ensure that no export of hazardous wastes is done other than as permitted under the convention. Under Article 4(1) (c), parties are required to prohibit the export of hazardous wastes where the state of import has not consented to the import. The consent must be in writing and must accompany the export of the hazardous wastes.[263]

Most of the waste electrical and electronic equipment (WEEE) is often transported to developing countries, where they extract valuable materials.[264] When a country exports the waste electrical and electronic equipment, then such export must be consented to by the state of import. Much of this research deals with recycling the waste electrical and electronic equipment (e-waste) to realize its economic capital while minimizing any consequence of pollution. Article 4(2) (e) mandates parties not to export hazardous wastes to developing countries that prohibit all imports either by legislation or because they cannot dispose of the wastes in an environmentally sound manner.

Further, Article 4(2) (f) requires that the information about a proposed transboundary movement of hazardous wastes be availed to the other state. It details the effect that such movement may have on human health and the environment. Article 4(7) (b) requires that hazardous wastes transported across boundaries be packaged, labeled, and transported according to generally accepted and recognized international rules and standards regarding packaging, labeling, and transportation. Most of the standards for packaging and labeling have already been discussed under

[262] Agbor, Avitus A. "The Ineffectiveness and Inadequacies of International Instruments in Combatting and Ending the Transboundary Movement of Hazardous Wastes and Environmental Degradation in Africa." *African Journal of Legal Studies*, vol. 9, no. 4, 2016, pp. 235-267.
[263] Okukpon, Irekpitan. "Towards the sustainable management of electronic waste in Nigeria: South Africa as a model." (2015) p. 99.
[264] Agbor, Avitus A. "The Ineffectiveness and Inadequacies of International Instruments in Combatting and Ending the Transboundary Movement of Hazardous Wastes and Environmental Degradation in Africa." *African Journal of Legal Studies*, vol. 9, no. 4, 2016, pp. 235-267.

Chapter 3 of this research. However, it is essential to note that waste electrical and electronic equipment is subject to the conference of parties (CoP) guidelines.

Additionally, Articles 6 and 7 deal with the transboundary movement of wastes through the mechanism of prior information and consent by the state of transit and import. A state must seek consent from all states where the wastes may pass when exporting wastes[265] The principle of notification and consent has also been discussed under Chapter 3 of this research.

5.1.3 Basel Convention Technical Guidelines

5.1.3.1 Draft Technical Guidelines on Transboundary Movements of E-Waste

The updated technical guidelines on transboundary movements of WEEE is a non-binding instrument developed by the Open-ended Working Group for 2018–2019 of the Basel Convention on their eleventh meeting.[266] The current updated guidelines summarize the provisions of the convention with particular emphasis on their application to e-wastes. The guidelines distinguish what qualifies as e-waste and what is not e-waste.[267] Further clarification is on when e-waste may be considered hazardous or non-hazardous.[268] Much of the distinction is similar and draws from the classification adopted by the Basel Convention as discussed above. Notably, paragraph 30 of the guidelines explains situations where used equipment should be regarded as waste, especially the equipment destined for disposal or recycling. Furthermore, the guidelines explain the circumstances where e-wastes may be transported across boundaries and the procedure to be followed according to Article 6 of the Convention.[269]

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[265] Id.
[266] Decision BC-12/5. *Draft Updated Technical Guidelines on Transboundary Movements of Electrical and Electronic Waste and Used Electrical and Electronic Equipment, in particular regarding the distinction between waste and non-waste under the Basel Convention*. 29 June 2018. Available at: http://www.basel.int/Implementation/PublicAwareness/NewsFeatures/Ewastetechnicalguidelines/tabid/5122/Default.aspx
[267] Id. pp. 9-14.
[268] Id. p. 14.
[269] Id.

5.1.3.2 Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones

The Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones, 2009, provides essential insights on developing a regulatory framework for recycling e-waste.[270] The document aims at striking a balance between economic efficiency and environmentally sound management of e-waste. Paragraph 6 of the Guidelines requires parties to develop a regulatory framework for recycling end-of-use mobile phones and balance the necessity of environmentally sound management and economic efficiency. Such a balance is achievable where factors such as authorizations, licenses, permits, or standards are factored in the regulatory framework.[271] Further, paragraph 6 of the Guidelines notes that investment in e-waste recycling should consider the Basel Principles of self-sufficiency, proximity, and minimum transboundary movement, as well as the necessity of economic efficiency. The guidelines are essential for recycling e-waste, particularly mobile phones, which are not otherwise provided for in the text of the Basel Convention. As a result, the content of the Guidelines is more direct and vital to the present research than the general provisions of the Basel Convention.

5.1.3.3 Guideline on Recovery and Recycling of End-of-Life Computing Equipment

The Guideline on Environmentally Sound Material Recovery and Recycling of End-of-Life Computing Equipment is another material under the Basel Convention that underpins the recycling of e-waste.[272] This document focuses on computers and reiterates the need to factor in authorizations, licenses, permits, or standards established in local, multinational, and international

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[270] Basel Convention Mobile Phone Partnership Initiative (MPPI), 2009e. *Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones*. Revised and approved text, 25 March 2009. Available from: http://basel.int/Implementation/TechnicalAssistance/Partnerships/MPPI/MPPIGuidelinesandGlossaryofTerms/tabid/3251/Default.aspx

[271] Id. para. 6.

[272] Basel Convention Partnership on Action for Computing Equipment (PACE), 20112013b. *Guideline on Environmentally Sound Material Recovery and Recycling of End-of-Life Computing Equipment*. Revised in 10 May 2013. Available from: http://www.basel.int/Implementation/TechnicalAssistance/Partnerships/PACE/PACEGuidelines,ManualandReports/tabid/3247/Default.aspx

laws. The Guideline notes the commercial aspects of trading in end-of-life computers and the possible transboundary movement. Paragraph 121 of the Guidelines provides that the convention's provisions on transboundary movement of hazardous wastes should apply to end-of-life computing equipment destined for material recovery and recycling. Further, Paragraph 123 notes that material recovery from electronic equipment is a mature commercial activity that needs to be done in an environmentally sound manner, even if it is to be achieved through Extended Producer Responsibility schemes. The Guidelines recommend that parties and signatories implement policies and programs that promote environmentally and economically sound material recovery and recycling of end-of-life computing equipment. It further notes that environmentally sound material recovery and recycling of end-of-life computing equipment requires setting up an effective recycling chain.

Paragraph 140 reiterates the critical principles of environmentally sound management of wastes. Recycling computers should factor in the principles of national self-sufficiency, proximity, least transboundary movement, and the necessity of economic efficiency. Therefore, these Guidelines are crucial in interpreting and enforcing the obligation entailed in the Basel Convention regarding e-wastes in the GCC.

5.2 Stockholm Convention on Persistent Organic Pollutants

The Stockholm Convention on Persistent Organic Pollutants is an international treaty to safeguard humans and the environment from the severe impacts of Persistent Organic Pollutants (POPs). The convention was adopted in May 2001 and entered into force in May 2004.[273] It has

[273] Pops.int. 2021. *Text of the Convention*. [online] Available at: <http://www.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx> [Accessed 8 May 2021].

184 members and 152 signatories with a Secretariat in Geneva, Switzerland.[274] All the GCC member states are state parties to the convention, making it the second universal convention that guides e-waste regulation within the GCC. The Stockholm Convention requires parties to eliminate or reduce the release of POPs into the environment.[275] Thus, the convention can be said to follow a precautionary perspective where in case of any threats of severe irreversible damage, little scientific certainty shall not warrant the postponement of cost-effective initiatives to mitigate the degradation of the environment.[276] The discussion on the precautionary principle can be found in Chapter 3 of this research.

The Stockholm Convention is a legally binding instrument for all members. All governments are required to report on their steps towards implementing the treaty regularly.[277] The convention is applicable to waste electrical and electronic equipment because most of the electronic equipment comprises plastics that may contain POPs. Further, commercial pentabromodiphenyl ether (c-PentaBDE) and specific congeners of commercial Octabromodiphenyl ethers (c-OctaBDE) are among the listed POPs under Annex A. The PBDEs (POP-PBDEs) are officially recognized as persistent organic pollutants (POPs) under the Stockholm Convention, which prohibits the production, use, import, and export with some defined exemptions.[278] Further, these POPs are included in recycled products, including electronic

[274]Chm.pops.int. 2021. *Status of ratifications of the Stockholm Convention*. [online] Available at: <http://chm.pops.int/Countries/StatusofRatifications/PartiesandSignatoires/tabid/4500/Default.aspx> [Accessed 8 May 2021].
[275] Bell, S. & McGillivray, D. 2006. *Environmental law* (Oxford, Oxford University Press).
[276] Heidelore, Fiedler "Stockholm convention on POPs: obligations and implementation." *The Fate of Persistent Organic Pollutants in the Environment*. Springer, Dordrecht, 2008. 3-12.
[277] Heidelore, Fiedler. Stockholm convention on POPs: obligations and implementation
[278] Sindiku, O., J. O. Babayemi, O. Osibanjo, M. Schlummer, M. Schluep, and R. Weber. "Assessing POP-PBDEs and BFRs in E-waste polymers in Nigeria." *Organohalogen compounds* 74 (2012): 1320-1223.

equipment. The recycling of e-wastes thus carries risks of causing harm to human health and the environment arising from the exposure to POPs.[279]

Article 3 of the Convention highlights the measures to reduce or eliminate releases from the intentional production and use of POPs. The convention provides that every party shall prohibit and take the legal and administrative measures to eliminate the production and utilization of chemicals listed in Annex A of the Convention.[280] Equally, every party shall also eliminate the import and export of the chemicals listed in Annex A.[281]

Further, Article 4 of the Convention provides that every Register shall encompass: a list of the types of specific exemptions reproduced from Annex A and Annex B and a list of the parties with specific exemptions included under Annex A or Annex B. Finally, it contains a list of the expiry dates for every registered specific exemption.[282] Article 5 of the Convention provides the measures to reduce or eliminate the releases from unintentional production. It provides that every party shall develop an action plan and, where necessary, regional or sub-regional action plan within two years after entry into force of the convention.[283] The action plan shall encompass an assessment of the current and projected releases, including developing and maintaining source inventories and release estimates. Secondly, the action plan shall include an evaluation of the effectiveness of e-waste laws and policies of the party and the strategies to achieve the obligations

[279] Stockholm Convention (2010). Technical Review of the Implications of Recycling Commercial Pentabromodiphenyl Ether and Commercial Octabromodiphenyl Ether. 6th POP Reviewing Committee meeting (UNEP/POPS/POPRC.6/2) and Annex (UNEP/POPS/POPRC.6/INF/6).
[280] Stockholm Convention, art. 3(1) (a).
[281] Id. Art. 3(2).
[282] The Secretariat of the Stockholm Convention. "Stockholm Convention on Persistent Organic Pollutants (POPs) as amended in 2009." 2009, www.env.go.jp/chemi/pops/treaty/treaty_en2009.pdf.
[283] Stockholm Convention, art. 5(a).

of paragraphs (I) and (II).[284] Article 5 also stipulates that every party shall enhance the application of available, feasible, and practical achievable and realistic measures.[285]

Moreover, Article 6 of the Convention relates to minimizing or eliminating releases from stockpiles and wastes. Every party is obliged to develop the necessary steps for identifying stockpiles consisting of or containing chemicals listed under Annex A or Annex B.[286] Further, every party must take the necessary measures to ensure that the listed wastes, including products and articles turning into wastes, are handled, collected, transported, and stored in an environmentally sound manner and disposed of in ways that ensure the POP content is destroyed and irreversibly transformed.[287] Every party shall also establish appropriate strategies to identify sites contaminated by chemicals listed in Annex A, B, or C and ensure environmental protection. Further, Article 6 underpins the environmentally sound management of POPs to protect human health and the environment.[288] The principle is conceptually similar to the one advanced under the Basel Convention, thus making both conventions significant in discussing the development of a regulatory framework on e-waste recycling.

5.3 Minamata Convention on Mercury

The Minamata Convention is a global convention with 128 signatories and 131 members adopted in 2013 and came into force in 2017.[289] The convention is developed to safeguard human health and the environment from emissions and releases of mercury and mercury compounds resulting from human activities. [290] The Minamata Convention highlights the measures associated

[284] Id. art. 5(a) (i- iv).
[285] Id. art. 5(b).
[286] Id. art. 6(a) (i).
[287] Stockholm Convention, art. 6(1) (d).
[288] Sindiku, O., J. O. Babayemi, O. Osibanjo, M. Schlummer, M. Schluep, and R. Weber. "Assessing POP-PBDEs and BFRs in E-waste polymers in Nigeria." *Organohalogen compounds* 74 (2012): 1320-1223.
[289]"Parties." *Minamata Convention on Mercury > Home*, www.mercuryconvention.org/Countries/Parties/tabid/3428/language/en-US/Default.aspx. Accessed 9 May 2021.
[290] Africa Clean Energy Technical Assistance Facility. *E-Waste Policy Handbook*. 2019, p. 20.

with the life cycle of mercury, controls, and reductions across a wide range of products, industries, and processes that utilize, release or emit mercury. Mercury is used for extracting materials and manufacturing goods such as electrical and electronic products, making it part of e-wastes.[291] Notably, all the GCC members are parties to the Minamata Convention, making it the third international convention related to e-waste that applies to the current research.[292]

Article 3 of the Convention relates to mercury supply sources and trade. All references to mercury involve the mixtures of mercury with other substances and alloys of mercury that have a minimum of 95% mercury concentration.[293] The mercury compounds are chloride, mercury (II) oxide, mercury (II) sulphates, mercury (II) nitrate, and cinnabar and mercury sulphide.[294] Article 3 stipulates that every party shall not allow primary mercury mining to be undertaken within its borders.[295] Further, every member shall be committed to identifying individual stocks of mercury or mercury compounds that exceed 50 metric tons and the sources of mercury supply generating stocks exceeding ten metric tons. Further, each party shall not allow the export of mercury except for parties that have forwarded the exporting party a written consent for utilization permitted under the convention and environmentally sound.[296] Like the Basel and Stockholm Conventions, the Minamata Convention underpins the principle of environmentally sound management of hazardous chemicals and wastes and the need for notification and consent.

[291] Id.
[292] "Parties." *Minamata Convention on Mercury > Home*, www.mercuryconvention.org/Countries/Parties/tabid/3428/language/en-US/Default.aspx. Accessed 9 May 2021.
[293] Minamata Convention, art. 3(1) (a).
[294] Id. Art. 3(1) (b).
[295] Id. Art. 3(3).
[296] Id. Art. 3(5).

5.4 Rotterdam Convention

The Rotterdam Convention is a global treaty established in 1998 to ensure nations' informed decision-making concerning the trade of hazardous chemicals.[297] All the GCC member states are parties to the Rotterdam Convention.[298] The convention highlights a list of chemicals and expects all parties seeking to export them to ascertain that the intended importing nation has consented to the import.[299] Further, the convention requires that every party seeking to export a chemical not listed and subject to a ban within its borders notify the importing state about the intended export.[300]

Article 6 of the Convention relates to the procedures for severely hazardous pesticide formulations. A developing nation facing challenges caused by severe hazardous pesticides in their territories can inform the Secretariat about listing the hazardous chemicals under Annex II. Consequently, the Secretariat shall gather data concerning the proposal.[301] The Chemical Review Committee shall design a draft decision guidance document according to the information in Annex I. Besides, Article 8 of the Convention relates to the chemicals in the voluntary prior informed consent procedure. The Article specifies that the Conference of Parties shall decide to list a chemical in Annex III if it fulfills the requirements for listing.

5.5 Montreal Protocol on Substances that Deplete the Ozone Layer

The 1987 Montreal Protocol relating to substances depleting the ozone layer has been a landmark agreement to reduce international production, consumption, and emissions of ozone-

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[297] "The Rotterdam Convention Now Has 159 Parties, with Turkey Depositing Its Instrument of Ratification on 21 September 2017." *BRSMeas*, www.pic.int/Countries/Statusofratification/PartiesandSignatories/tabid/1072/language/en-US/Default.aspx.
[298] Id.
[299] Lundgren, Karin. *The global impact of e-waste: addressing the challenge*. International Labour Organization, 2012, p. 34.
[300] Id.
[301] United Nations (UN). *The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (1998)*. 1998, www.jus.uio.no/lm/hazardous.chemicals.and.pesticides.prior.informed.consent.trade.rotterdam.convention.1998/portrait.pdf.

depleting substances (ODS). The ODS refers to greenhouse gases contributing to climate change.[302] The convention defines controlled substances in Annex A, B, C, E, or F as isomers of any substance unless specified in the relevant Annex. Article 2A of the Convention specifies that every party shall ensure that its consumption of controlled substances in Group I of Annex A does not exceed its calculated consumption in 1986. Further, the Article stipulated that every party was to ensure that its consumption does not exceed zero unless the consumption is related to servicing refrigeration or air conditioning equipment. Thus, the provisions aimed at reducing the production of Ozone-depleting substances in the atmosphere by all parties.

Article 4 of the Convention relates to the control of trade with non-parties. As of January 1990, every party was anticipated to ban the importation of controlled substances listed in Annex B. Every party was required to ban the importation of controlled substances stated in Annex A from a non-party. Further, each party in the Protocol was needed to serve the Secretariat with statistical data relating to production, imports, and exports of the controlled substances.[303] Therefore, the Montreal Protocol provisions have been effective in reducing ozone depletion.

5.6 Bamako Convention

The Bamako Convention was passed in response to the increased dumping of hazardous wastes in African nations. Africa nations have limited technical expertise and administrative capabilities for monitoring, detecting, and handling hazardous waste, making them vulnerable to illegal dumping. The concerns led to the adoption of the Bamako Convention to ban the import into Africa and control the transboundary movement of hazardous wastes within Africa. [304]

[302] Velders, Guus JM, et al. "The importance of the Montreal Protocol in protecting climate." *Proceedings of the National Academy of Sciences* 104.12 (2007): 4814-4819.
[303] UNEP Ozone Secretariat. *Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer*. 2018, ozone.unep.org/sites/default/files/MP_handbook-english-2018.pdf.
[304] Jaffe, Daniel. "The International Effort to Control the Transboundary Movement of Hazardous Waste: The Basel and Bamako Conventions." *ILSA J. Int'l & Comp. L.* 2 (1995): 123

Notably, the Bamako Convention applies to all the hazardous wastes in Annex I. Further, all the wastes considered as hazardous by local laws of the state of import or export are considered hazardous under the Bamako Convention.

The Bamako Convention requires all parties to intervene to prevent hazardous wastes from entering Africa from non-contracting nations. Under the convention, all parties must monitor their waterways to prevent dumping in any water, including the seas. Notably, a country can be penalized through monetary sanctions for violating the provisions of the Bamako Convention. Further, the convention prohibits the release of harmful substances into the air, thus preventing pollution.

Notably, Article 4 of the Bamako Convention relates to the general obligations of members. All parties must take the necessary legal and administrative measures in their territories to prohibit the importation of hazardous wastes into Africa from non-party states. The parties are expected to forward all data regarding cases of illegal hazardous waste import operations within their jurisdictions to the Secretariat for prompt actions to be taken. [305] Further, parties are expected to prohibit the dumping of hazardous wastes at sea and in internal waters. Article 3 also encourages the adoption of precautionary measures. Every party must adopt and implement a preventative and precautionary approach when tackling pollution challenges to prevent the release of hazardous wastes to the environment.

5.7 Waste Shipment Regulation (EC) № 1013/2006

The regulation applies to the shipment of wastes within the community with or without transit through third countries and within member states. The regulation implements the Basel Convention in the EC law and the OECD provisions on trans-frontier waste movement. Notably,

[305] Lex Mercatoria. *Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa (1991)*. www.jus.uio.no/lm/hazardous.waste.ban.afrian.import.bamako.convention.1991/landscape.pdf.

Regulation EC No 1013/2006 replaced Regulation (EEC) No 259/93. It aims to support, simplify and specify the current processes for controlling waste shipments to mitigate illegal shipping. However, the regulation does not apply to most ship-generated waste and waste from vehicles, trains, and ships.

The regulation prohibits exporting wastes to third nations except for EFTA countries that are parties to the Basel Convention. Annex V of the Regulation lists all the types of waste prohibited from the shipment. [306] Further, waste shipment involves an agreement between an individual responsible for shipping the waste, the consignee and notification needed, and a financial guarantee. All member states are expected to outline the rules and penalties that apply to the infringement of the provisions. Further, the regulation requires all members to offer inspections of establishments and undertakings according to the Directive 2006/12/ EC.

5.8 Restriction of Hazardous Substances Directive (RoHS)

The EU has been generating a high volume of waste electrical and electronic equipment each year. Notably, electronic and electronic equipment waste has hazardous chemicals that are harmful to life. As a result, the EU laws have placed restrictions on the utilization of hazardous substances through the RoHS Directive. The Directive restricts the utilization of lead, cadmium, mercury, PBDE, and hexavalent chromium. The RoHS Directive aims at mitigating the risks posed to humans and the environment concerning the management of EEE. [307] The Directive achieves its mission by prohibiting the utilization of certain hazardous substances in the EEE, which can be replaced by alternatives. The prohibited substances encompass heavy metals, flame retardants, and plasticizers. Further, the RoHS Directive encourages EEE recycling and its components to contain

[306] IEEP. "Manual of European Environmental Policy." 2014, ieep.eu/uploads/articles/attachments/c864ccc0-3b5c-4fa0-88c5-43237a1c5f95/6.3_Waste_shipment_-_final.pdf?v=63664509871.
[307] European Commission. "Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS)." ec.europa.eu/environment/topics/waste-and-recycling/rohs-directive_en

only fewer hazardous substances. The Directive also ensures a level playing ground for manufacturers and EEE importers in the European market.

5.9 Waste Electrical and Electronic Equipment Directive (WEEE)

There has been a significant increase in production and utilization of EEE in the past three decades. As a result, WEEE is the largest growing waste source worldwide. In response, the WEEE Directive was developed to encourage manufacturers to design and produce EEE based on end-of-life management. The Directive was signed and put in effect in early 2003. [308] The main aim of the WEEE Directive is to prevent the generation of WEEE and enhance the reuse, recycling, and recovery to decrease their environmental impacts.

The Directive requires that users of EEE are informed about their functions in the WEEE recovery system. Notably, the EEE must be labeled to minimize the disposal of WEEE as unsorted municipal wastes. Further, manufacturers are needed to inform recycling operators about the material content of the equipment. Notably, the Directive 2012/19/EU requires recovery, recycling, and reuse standards for WEEE to be developed by the European standardization organizations.[309] The Directive also requires that minimum monitoring requirements for the shipment of WEEE are initiated to support the enforcement of the WEEE Directive.

5.10 Registration, Evaluation, Authorizations, and Restriction of Chemicals (REACH)

REACH is a European Union regulation adopted to protect human health and the environment from risks posed by chemicals while ensuring market competitiveness of EU chemicals. The REACH offers alternative methods for assessing hazardous chemicals. It also enhances the protection of human health and the environment via better and earlier determination

[308] Ylä-Mella, Jenni, et al. "Overview of the WEEE Directive and its implementation in the Nordic countries: national realisations and best practices." *Journal of Waste Management* 2014 (2014).
[309] Ylä-Mella, Jenni, et al. Overview of the WEEE Directive and its implementation in the Nordic countries: national realisations and best practices.

of the intrinsic properties of chemicals. [310] It also undertakes its functions through the registration, evaluation, authorization, and restriction of chemicals. Further, the REACH promotes innovation leading to the competitiveness of the EU chemicals industry.

The REACH assigns the chemical industry the responsibility to manage risks resulting from chemical substances. Notably, the industry is expected to offer safety information regarding the substances. Further, the manufacturers and importers are required to collect data relating to the properties of chemical substances to enable their safe handling. [311] The information is to be registered in a central database in the European Chemicals Agency. The REACH Regulation also requires the assessment of suspicious chemicals and creating a public database where users and experts can find data related to hazardous chemicals.

5.11 Waigani Convention

The Waigani Convention came into force in October 2001. It refers to the convention to ban the importation into forum island countries of hazardous and radioactive wastes and control the transboundary movement of hazardous wastes within the South Pacific Region. The Waigani Convention is designed on the Basel Convention framework. It encompasses the regional execution of global hazardous waste control systems, including the Basel, Rotterdam, and Stockholm Conventions. [312] Notably, the convention's territorial coverage encompasses every party's exclusive economic zone of 200 nautical miles, like the Basel Convention.

The Waigani Convention aims at reducing and eliminating the transboundary movements of hazardous and radioactive wastes. It seeks to decrease the production of hazardous and toxic wastes in the Pacific region and ensure that waste disposal is undertaken in an eco-friendly manner. Just like the Basel Convention, the Waigani Convention is Annex-driven. The Annexes describe

[310] European Commission. "REACH." ec.europa.eu/environment/chemicals/reach/reach_en.htm.
[311] European Commission. "REACH." ec.europa.eu/environment/chemicals/reach/reach_en.htm.
[312] SPREP. "Waigani Convention." www.sprep.org/convention-secretariat/waigani-convention

the parties' obligations to reduce and control the movement and generation of hazardous wastes in Annex I and those that have properties listed in Annex II.

All parties are required to take appropriate measures to ban the import and export of hazardous waste to and from the convention area as stipulated in Article 4.1. The parties should prohibit the dumping of hazardous wastes and radioactive wastes in the Convention Area (4.2). Further, member states are required to ensure a reduced generation of hazardous wastes, as highlighted in Article 4, paragraph 4. [313] The parties must avail adequate treatment and disposal facilities to ensure sustainable management of wastes in the Convention area (4.5).

Conclusion

This chapter discussed the obligations of GCC states under the different conventions, including the Basel, Stockholm, Rotterdam, and Minamata conventions. Countries' regulatory frameworks for the recycling of e-wastes rely on their commitments to international conventions. Therefore, the chapter has discussed the international conventions that influence the GCC countries' e-waste management laws, policies, and programs. As established in this chapter, most states are parties to the international and regional conventions that regulate hazardous chemicals, electrical and electronic equipment wastes. The Basel Convention is the most relevant treaty that binds countries and offers the most critical policy and regulatory framework on the transboundary movement of e-waste. The convention's primary objective is to minimize waste generation by member states by requiring them to consider the social, economic, and technological aspects of hazardous waste generation.

Further, all GCC member states are members of the Stockholm Convention on Persistent Organic Pollutants. The convention aims at protecting humans and the environment from the

[313] SPREP. "Waigani Convention." www.sprep.org/convention-secretariat/waigani-convention

adverse effects of Persistent Organic Pollutants (POPs). The convention is a legally binding instrument that influences states' management of e-wastes to prevent damage by the POPs.

Similarly, the Rotterdam Convention discussed in this chapter is critical in regulating countries' handling and trade in hazardous wastes. The chapter has also discussed the Minimata Convention essential in protecting human health and the environment from emissions and releases of mercury. Notably, e-wastes contain mercury elements that pose significant risks. Countries are required to manage the lifecycle of mercury by controlling its release from products and industries. The conventions discussed in this chapter are instrumental in ensuring that countries establish measures to curb the release of hazardous e-waste products into the environment. Further, the conventions influence the environmental regulatory frameworks of the GCC member states, as will be discussed in chapter 6 in terms of their domestication in the national laws.

The next chapter shall continue the discussion of the regulatory framework for recycling e-waste within the GCC. Additionally, the chapter will look into the status of the conventions discussed in this chapter by the GCC member states through domestic legislation. It will also discuss the trends in e-waste recycling, import, and export within and outside the GCC.

CHAPTER 6

STATUS OF E-WASTE LAWS, ENFORCEMENT, AND MANAGEMENT WITHIN THE GCC

6.0 Introduction

The GCC region has experienced a surge in population growth and urbanization associated with improved living standards. Population growth and rapid urbanization have caused a substantial increase in e-waste generation. Additionally, technological advancement has made the lifespan of electronics shorter, creating an e-waste problem for the GCC countries.[314] As part of addressing the e-waste problems, some GCC countries have established national laws under international Conventions and principles. This chapter discusses the domestication status of the international Conventions and principles by the GCC countries (i.e., Bahrain, Kuwait, Oman, Saudi Arabia, Qatar, and UAE). The conventions discussed are the Basel Convention 1989, Stockholm Convention 2001, Minamata Convention 2013, Rotterdam Convention 1998, and Montreal Protocol 1987. Further, this chapter discusses the environmental laws, decrees, regulations, and unified codes for the Gulf Cooperation Council. Finally, the national environmental laws, regulations, and mandates applicable to e-waste are discussed for every GCC country.

6.1 Status of Domestication of International E-Waste Conventions and Principles

6.1.1 Basel Convention, 1989

6.1.1.1 Bahrain

The Basel Convention has been domesticated in Bahrain environmental law through the Legislative Decree No.21 of 1996 in Respect with the Environment. The Decree is critical in regulating the movement of hazardous wastes from Bahrain to other nations to mitigate their

[314] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.1-4 https://www.researchgate.net/publication/309537926_Electronic_Waste_Management_and_security_in_GCC_Countries_A_Growing_Challenge

transfer to the least developed countries. The Supreme Council for the Environment issues the required licenses that permit the exportation of wastes outside the Kingdom of Bahrain for treatment, recycling, or reuse.[315] The entire export process follows the provisions of the Basel Convention, indicating its domestication within the Kingdom's environmental regulations.

Article 6 of the Decree prohibits any person from using the environment in a way that causes environmental pollution, deterioration, and damage to natural resources. Thus, there must be appropriate and reasonable exploitation of the environment.[316] Article 18 of the law prohibits the storage and disposal of wastes in ways that violate the set systems, standards, and procedures established by the competent environmental authority.

6.1.1.2 Kuwait

Kuwait ratified the Basel Convention on the Movement of Hazardous Wastes in 1993. However, information on the domestic laws relating to the convention remains scanty. Kuwait transmitted the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution to the Basel Secretariat, which is the enabling law.[317] The regional law applies to the marine environment and is not specific to e-waste or hazardous waste. Nonetheless, the country prohibits the transportation of hazardous wastes from the industrialized nations to other concerned countries.[318] However, there is no evidence of domestication of the Basel Convention in Kuwait's environmental laws.

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[315] Kingdom of Bahrain, Supreme Council for Environment. Exporting waste abroad. https://www.sce.gov.bh/en/ExportingWasteAbroad?cms=iQRpheuphYtJ6pyXUGiNqn4yFZX70Gnc
[316] Legislative Decree No.21 of 1996 in Respect with the Environment. P.9
[317] "Basel Convention > Countries > Agreements > Multilateral Agreements." *Basel Convention*, www.basel.int/Countries/Agreements/MultilateralAgreements/tabid/1518/Default.aspx.
[318] KUNA. "Kuwait announces ratification of Basel Convention on Movement of Hazardous Waste." https://www.kuna.net.kw/ArticlePrintPage.aspx?id=1653871&language=en

6.1.1.3 Oman

Oman accepted the Basel Convention on the Transboundary Movement of Hazardous Wastes and Their Disposal in 1995 (RD 119/1994).[319] The country established the Royal Decree No. 114/2001 that focuses on environment conservation and pollution prevention following the ratification of the Basel Convention. Article 23 of the law states that no ship shall discharge environmental pollutants in the territorial waters or the exclusive economic zone.[320] Further, the owner of a ship with hazardous waste shall follow instructions provided by the environmental inspector and keep relevant records.

Article 7 of the Decree prohibits the use of Oman's environment for disposing of environmental pollutants in quantities and types that may adversely impact its intactness and natural resources, conservation areas, and the historical and cultural heritage of Oman.[321] Further, Article 12 prohibits a waste generator or site owner from discharging any environmental pollutants at the final discharge locations except when the discharge level is less than the maximum discharge amount permitted by the environmental regulations. The Decree regulates the movement and disposal of hazardous wastes in and out of Oman as provided in the Basel Convention, although in a maritime context.

6.1.1.4 Qatar

The Basel Convention has been applied in Qatar by enacting the Executive By-Law for the Environment Protection Law, the Decree-Law No. 30 in 2002. The law defines transboundary movement as the movement of hazardous wastes from a location under the jurisdiction of a country

[319] Astolfi, Agnes (2015). Overview of Oman's Legislation on Waste. Muscat, SustainableOman. https://sustainableoman.com/wp-content/uploads/2018/04/Policy-Overview-Infographic.pdf
[320] Royal Decree No. 114/2001. Issuing the law of the environment and prevention of pollution. P.11. Available at: http://www.vertic.org/media/National%20Legislation/Oman/OM_Law_Conservation_Environment_114-2001.pdf
[321] Royal Decree No. 114/2001. Issuing the law of the environment and prevention of pollution. P.11. Available at: http://www.vertic.org/media/National%20Legislation/Oman/OM_Law_Conservation_Environment_114-2001.pdf

to or through an area under the state jurisdiction of another nation.[322] Additionally, Article 22 of the law applies to managing and handling wastes and hazardous materials as established in the Basel Convention. The law requires competent authorities to offer licenses to hazardous waste and materials treatment, management, and handling facilities according to the waste handling locations' type, use, and suitability established by the By-Law in Annex 5.[323] Article 23 further prohibits any importation of hazardous waste or entry, transit, dumping, and burial in Qatar.

Most importantly, Article 24 represents the Basel Convention requirements on the transboundary movement of hazardous waste. The law states that ships or vessels transporting hazardous wastes are not allowed to navigate the Qatar territorial sea or the Exclusive Economic Zone of Qatar unless authorized by a responsible authority after the approval of the Supreme Council.[324] Additionally, several conditions are provided in Article 24 that must be met before the Council approves any movement of hazardous waste within Qatar. The conditions include providing sufficient data about the hazardous wastes on transit, their sources, and their destination. Evidence of the exporter and importer's approval must also be availed before approval.

6.1.1.5 Saudi Arabia

The Basel Convention has been domesticated in Saudi Arabia through the General Environmental Regulations and Rules of Implementation. Notably, Article 14 prohibits the movement of hazardous, poisonous, or radioactive wastes into the Kingdom's territorial waters and exclusive economic zone. Further, all responsible authorities must adhere to the national

[322] Executive By-Law for The Environment Protection Law, Issued vide the Decree Law No.30 for the year 2002. P.2. Available at: http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-NATLEG-NOTIF-Qatar01-DECREE30.2002.English.pdf

[323] Executive By-Law for The Environment Protection Law, Issued vide the Decree Law No.30 for the year 2002. P.18. Available at: http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-NATLEG-NOTIF-Qatar01-DECREE30.2002.English.pdf

[324] Executive By-Law for The Environment Protection Law, Issued vide the Decree Law No.30 for the year 2002. P.19. Available at: http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-NATLEG-NOTIF-Qatar01-DECREE30.2002.English.pdf

regulations, standards, guidelines, and instructions regarding the generation, trade, storage, treatment, recycling, and transportation of hazardous wastes.[325] The Articles follow the Basel Convention's requirements on transboundary movements and disposal of hazardous wastes ratified by the Kingdom of Saudi Arabia.

6.1.1.6 United Arab Emirates

The Basel Convention is domesticated in the United Arab Emirates under Federal Law No. (24) of 1999 to protect and develop the environment. Article 59 of the law provides that any disposal of hazardous wastes must only be undertaken based on the conditions determined by the Executive Order. The setting of facilities for treating hazardous wastes without licensing and approval by competent authorities is prohibited under Article 59 of the law.[326] Further, Article 60 states that any inspection of the transportation and disposal of hazardous wastes across the land and marine water boundaries must be done according to the controls provided by the Executive Order.

6.1.2 Stockholm Convention, 2001

6.1.2.1 Bahrain

Bahrain passed Ministerial Order No. 4 of 2006 regarding the management of hazardous chemicals. The Ministerial Order establishes a proper monitoring and management system for handling hazardous chemical wastes as listed in the Ministerial Order No. 7 of 2002. Notably, the Ministerial Order No.7 of 2002 creates control over the importation and use of banned and restricted chemicals specified by the General Directorate for the Protection of the Environment and Wildlife. Further, Ministerial Order No. 110 of 2006 requires the establishment of a national

[325] General Environmental Regulations And Rules for Implementation. P.32. https://elaw.org/system/files/attachments/publicresource/saudiarabia.General%20Environmental%20Regulations.pdf
[326] Federal Law No. (24) Of 1999 for the protection and develop of the environment. P.25. Available at: http://www.vertic.org/media/National%20Legislation/United%20Arab%20Emirates/AE_Federal_Law_Environment_24_1999.pdf

committee to register pesticides.[327] The Orders are based on the principles of the Stockholm Convention regarding control of persistent organic pollutants that Bahrain ratified.

6.1.2.2 Kuwait

Kuwait successfully domesticated the Stockholm Convention by passing Law No. 42 of 2014, the country's Environment Protection Law. Article 42 of the law deals with the control of persistent organic pollutants. For instance, a competent authority is mandated by the law to determine the conditions for handling insecticides, fertilizers, and soil-improving materials to prevent environmental pollution.[328] Further, Article 43 of the law prohibits using pesticides, organic chlorine insecticides, and other organic chemical compounds in agriculture, health, and other activities unless the conditions, safeguards, and controls given by an Executive By-Law are fully met.

6.1.2.3 Oman

Oman has not enacted a law relating to the control of persistent organic pollutants. However, Royal Decree No. 114/2001 is the general law for protecting the environment from pollutants such as Persistent Organic Pollutants. Specifically, Article 7 of the law prohibits using Oman's environment to dispose of environmental pollutants.[329] Further, Article 14 provides that pollutants shall not exceed the maximum allowable limits.

6.1.2.4 Qatar

Qatar promulgated Law No.30 of 2002, the Law of the Environment Protection. Article 29 of the law relates to controlling persistent organic pollutants as provided in the Stockholm

[327]The Supreme Council of Environment. "Bahrain National Profile to Assess the National Infrastructure for Chemical Safety." P. 60. https://cwm.unitar.org/national-profiles/publications/cw/np/np_pdf/Bahrain_National_Profile_update.pdf
[328] Law No. 42 of 2014 Promulgating The Environment Protection Law.p.32. http://extwprlegs1.fao.org/docs/pdf/kuw142030E.pdf
[329] Royal Decree No. 114/2001 Issuing The Law On Conservation Of The Environment And Prevention Of Pollution. p.9 http://extwprlegs1.fao.org/docs/pdf/oma98254E.pdf

Convention.[330] The law prohibits spraying pesticides or chemical compounds for agricultural, public health, and other purposes to protect the environment from pollution. Besides, Qatar has an elaborate National Implementation Plan (NIP) for Stockholm Convention developed by the Supreme Council for the Environment and Natural Reserves (MoE).[331]

6.1.2.5 Saudi Arabia

Saudi Arabia has not formally domesticated the Stockholm Convention rules into its national environmental laws. However, the General Environmental Regulations and Rules for Implementation provide sufficient safeguards and controls for the use of persistent organic pollutants.[332] The regulations establish the environmental general protection standards, which offer the applicable policy for controlling pollution in the Kingdom. Despite the scanty information on the specific laws on the implementation of the convention, the Kingdom actively participates in the Conference of Parties (COP) meetings.[333]

6.1.2.6 United Arab Emirates

The UAE is in the process of domesticating the Stockholm Convention on POPs standards into its environmental law. The country has established a national implementation plan to mitigate the risks of persistent organic pollutants and protect the environment at every stage from production, use, and handling. Additionally, the UAE plans to take measures towards implementing regulatory obligations and reducing organic pollutants.[334] The key priority in UAE

[330] Law No. 30 of 2002 promulgating the law of the environment protection. https://www.almeezan.qa/LawView.aspx?opt&LawID=4114&language=en
[331] The State of Qatar Ministry of Environment National Implementation Plan (NIP) for Stockholm Convention on Persistent Organic Pollutants (POPs). http://extwprlegs1.fao.org/docs/pdf/qat199284E.pdf
[332] General Environmental Regulations And Rules for Implementation. P.54. https://elaw.org/system/files/attachments/publicresource/saudiarabia.General%20Environmental%20Regulations.pdf
[333] "Saudi Arabia Takes Part, in Basel, Rotterdam, Stockholm Conventions, in Geneva the Official Saudi Press Agency." www.spa.gov.sa/viewfullstory.php?lang=en&newsid=1624366.
[334] FAO. UAE national implementation plan under the Stockholm Convention on Persistent Organic Pollutants (POPs). http://www.fao.org/faolex/results/details/en/c/LEX-FAOC202863/

as of December 2020 is to develop national legislation relating to the management of persistent organic pollutants, including restricted pesticides.

6.1.3 Minamata Convention, 2013

6.1.3.1 Bahrain

His Majesty King Hamad bin Isa Al Khalifa ratified the Minamata Convention on mercury by issuing Law 14/2021. The law requires that the prime minister and ministers foresee the execution of the provisions of the law after it comes into effect upon the official gazettement.[335] Notably, Law 14/2021 will regulate the inclusion of mercury into products and its effects on the environment and human health.

6.1.3.2 Kuwait

Kuwait signed the Minamata Convention on mercury to control the use and trade of the toxic substance. The country seeks to prevent health damage and pollution resulting from mercury.[336] However, there are no established laws regarding the control of mercury even after ratifying the Minamata Convention.

6.1.3.3 Oman

Oman ratified the Minamata Convention in 2020 through a Royal Decree 58/2020.[337] The ratification seeks to enhance control of mercury within the country to prevent health damage and pollution related to the toxic metal. However, there are no laws established regarding the Minamata Convention to control mercury use since the official gazettement of the Royal Decree 58/2020.

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[335] HM King ratifies, issues law 14/2021. https://www.bna.bh/en/HMKingratifiesissuesLaw142021.aspx?cms=q8FmFJgiscL2fwIzON1%2BDmu5VAmFXNesF7%2Fu90jlNgY%3D

[336] KUNA. "Kuwait signs treaty at UN conference to control mercury use, trade." https://www.kuna.net.kw/ArticleDetails.aspx?id=2338585&language=en

[337] Royal Decree 58/2020 Approving the accession of the Sultanate of Oman to the Minamata Convention on Mercury. https://mjla.gov.om/eng/legislation/decrees/details.aspx?Id=1197&type=L

6.1.3.4 Qatar

Qatar joined the Minamata Convention on Mercury in 2017, becoming the 125th member.[338] However, the country has not created specific national legislation in effect to the convention. Qatar has established a national plan for eliminating mercury to reduce its risks and damage to human health and the environment.[339] However, the national program has not been translated into particular legislation to enhance proper controls and safeguards on mercury.[340]

6.1.3.5 Saudi Arabia

Saudi Arabia ratified the Minamata Convention on Mercury in 2019. However, the convention has not been domesticated into Saudi environmental laws. The country controls mercury use and pollution through the General Environmental Regulation and Rules of Implementation.[341]

6.1.3.6 United Arab Emirates

The UAE has not established national laws based on the Minamata Convention on Mercury. The country controls mercury use and pollution through Decree No. 42 of 2009 relating to comprehensive environmental health and safety.[342]

6.1.4 Rotterdam Convention, 1998

6.1.4.1 Bahrain

Bahrain has domesticated the treaty on promoting information exchange and requires exporters of hazardous chemicals to embrace proper labeling of hazardous wastes. The country established Law 14/2012 to enhance shared responsibilities concerning the importation of

[338] Qatar joins Minimata Convention on Mercury. http://www.mme.gov.qa/cui/view.dox?id=702&contentID=8072&siteID=2
[339] National progam on the elimination of mercury in the State of Qatar. https://www.un.org/esa/dsd/susdevtopics/sdt_pdfs/meetings/ws1209/presentations/al-sulaiti.pdf
[340] UNDESA), Secretariat of the Stockholm Convention, and UNEP. "Practices in the Sound Management of Chemicals." P. 60. https://sustainabledevelopment.un.org/content/documents/41Practices%20in%20the%20Sound%20Management%20of%20Chemicals.pdf
[341] General Environmental Regulations And Rules for Implementation. P.32. https://elaw.org/system/files/attachments/publicresource/saudiarabia.General%20Environmental%20Regulations.pdf
[342] Decree No. (42) Of 2009 concerning Abu Dhabi EHSMS. P.3

hazardous chemicals.[343] The law aims at assisting in the control of the use and trade of hazardous chemicals to prevent environmental pollution and promote human health.

6.1.4.2 Kuwait

Kuwait has ratified the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. However, there is no national legislation under the Rotterdam Convention. Notably, the country's law relating to the control of hazardous chemicals and pesticides is within law No.42 of 2014, which promulgated the Environment Protection Law.[344]

6.1.4.3 Oman

Similar to other GCC countries, Oman has not passed national legislation under the Rotterdam Convention. Notably, Oman has ratified the Rotterdam Convention but lacks a legal framework to implement the convention rules. The Royal Decree No. 114/2001 is the primary law on Oman's environmental conservation and pollution prevention.[345]

6.1.4.4 Qatar

Qatar is a member state of the Rotterdam Convention. It acceded to the convention on 10th December 2004 and became a party on 10th March 2005.[346] However, the country has not established a law based on the Convention rules regarding information exchange on exporting hazardous chemicals among countries. However, Qatar has actively participated in the meetings and Conference of Parties under the Rotterdam Convention.[347]

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[343] Kingdom of Bahrain. Supreme Council for Environment. "International Conventions." https://www.sce.gov.bh/en/InternationalConventions?cms=iQRpheuphYtJ6pyXUGiNqqgHuL3%2f%2fWF0
[344] Law No. 42 of 2014 Promulgating The Environment Protection Law.p.34 http://extwprlegs1.fao.org/docs/pdf/kuw142030E.pdf
[345] Royal Decree No. 114/2001 Issuing The Law On Conservation Of The Environment And Prevention Of Pollution http://extwprlegs1.fao.org/docs/pdf/oma98254E.pdf
[346] "The Rotterdam Convention Now Has 159 Parties, with Turkey Depositing Its Instrument of Ratification on 21 September 2017." *BRSMeas*, www.pic.int/Countries/Statusofratification/PartiesandSignatories/tabid/1072/language/en-US/Default.aspx.
[347] "Global Praise for Qatar's Commitment to Rotterdam and Stockholm Conventions." *GulfTimes*, 14 Mar. 2020, https://m.gulf-times.com/story/658436/Global-praise-for-Qatar-s-commitment-to-Rotterdam-and-Stockholm-Conventions

6.1.4.5 Saudi Arabia

Similar to other GCC countries, the Kingdom of Saudi Arabia has not created a law based on the Rotterdam Convention rules. Saudi Arabia continues to rely on the General Environmental Regulations and Rules of Implementation as the legal framework for environmental protection.[348] Notably, Saudi Arabia is a member of the Rotterdam Convention.

6.1.4.6 United Arab Emirates

The United Arab Emirates is a member of the Rotterdam Convention, having ratified the convention in 2002. However, the country has not established law under the Rotterdam Convention. The United Arab Emirates lacks elaborate provisions on the exchange of information on hazardous chemicals under the convention.

6.1.5 Montreal Protocol, 1987

6.1.5.1 Bahrain

Bahrain ratified the Montreal Protocol through a Decree 32/2013 to control substances that deplete the Ozone layer.[349] However, the country has not enacted legislation based on the Montreal Protocol.

6.1.5.2 Kuwait

Kuwait has domesticated the Montreal Protocol under Law No. 42 of 2014, Promulgating the Environment Protection Law. Article 62 of the law prohibits the import, export, or manufacture of materials prescribed in the attachments (B, C, E) of the Montreal Protocol unless stated otherwise.[350] Thus, Kuwait has adequate legal safeguards to control substances that deplete the Ozone layer.

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[348] General Environmental Regulations And Rules for Implementation. https://elaw.org/system/files/attachments/publicresource/saudiarabia.General%20Environmental%20Regulations.pdf

[349] Kingdom of Bahrain. Supreme Council for Environment. "International Conventions." https://www.sce.gov.bh/en/InternationalConventions?cms=iQRpheuphYtJ6pyXUGiNqqgHuL3%2f%2fWF0

[350] Law No. 42 of 2014 Promulgating The Environment Protection Law.p.37 http://extwprlegs1.fao.org/docs/pdf/kuw142030E.pdf

6.1.5.3 Oman

Oman has enacted a law based on the Royal Decree No. 114/2001 that ratified the Montreal Protocol relating to the Ozone Depleting Substances. The Ministerial Decision 243/2005 is the regulation for controlling and managing ozone-depleting substances.[351] The regulation issues directives on the use, importation, and handling of controlled substances that are deemed to deplete the Ozone layer.

6.1.5.4 Qatar

Qatar has a national law based on the Montreal Protocol on controlling and managing Ozone-depleting substances. The country enacted Law No.21 of 2007 under Decree No. 23 of 1999, ratifying the Montreal Protocol of 1987.[352] Article 2 of the legislation prohibits the import, export, or re-export of controlled substances without permission from the Council.

6.1.5.5 Saudi Arabia

Saudi Arabia Ministry of Environment, Water and Agriculture created a bill for environmental protection. Article 22 of the bill prohibited all persons and companies from importing, exporting, trading, producing, or using Ozone-depleting substances listed by the National Center for Environmental Compliance Control without permission from the relevant authorities.[353] Thus, Saudi Arabia is making critical steps to enact laws to control Ozone-depleting substances based on the Montreal Protocol.

6.1.5.6 United Arab Emirates

The United Arab Emirates has established a law to control Ozone-depleting substances under the Montreal Protocol. The Cabinet Resolution No. 26 of 2014 provides the basis for the national

[351] MD 243/2005 regulation for the control & management of ozone depleting substances. https://www.soharportandfreezone.com/PDF/Complete%20pack%20Omani%20Environmental%20Regulations,%20International%20References%20Documents%20and%20SEU%20Guidance%E2%80%A6.pdf
[352] Law No.21 of 2007 on the control of the Ozone-depleting substances. https://www.almeezan.qa/LawView.aspx?opt&LawID=2552&language=en
[353] Environmental Bill. https://www.jetro.go.jp/ext_images/world/middle_east/sa/law/pdf/Environmental_Bill_ENG.pdf

regulation of Ozone-depleting substances.[354] The Resolution has 21 articles that offer rules for importing, exporting, and re-exporting the ozone-depleting substances and the equipment or products containing them.

6.2 Environmental Laws, Regulations, Decrees and Unified Codes by the Gulf Cooperation Council

6.2.1 General Regulations of Environment in the GCC States, 1997

The massive developmental growth experienced among the GCC countries has led to adverse environmental impacts over the years.[355] Therefore, the direct link between development and environmental sustainability requires general rules and regulations to guarantee development and environmental protection among the GCC countries. Consequently, the Supreme Council of the GCC agreed on various initiatives during the 6th session in Muscat, Oman, in 1985 to establish a robust system for safeguarding the environment, including the fundamental rules for environmental protection.[356] The GCC Secretariat General and the member states established general regulations, bases, and procedures for protecting the environment in the region.

The Basic Rules are critical components of the general principles relating to environmental protection in the GCC. The environment is defined as the human surroundings such as water, air, atmosphere, and land and what the surroundings, like plants, animals, human activities, natural regulations, and materials. As mentioned in the general principles, the human being refers to the integral aspect of the environment that lives and utilizes environmental resources. Article 3 of the Basic Rules specifies that every individual has a fundamental right to live a convenient life with

[354] Cabinet Resoluton No.26 of 2014 concerning the national regime of Ozone depleting substances. http://www.fao.org/faolex/results/details/en/c/LEX-FAOC185893/
[355] General Regulations Of Environment In The GCC States 1997. P.1-2. http://www.gcc-sg.org/en-us/CognitiveSources/DigitalLibrary/Lists/DigitalLibrary/Environment/1274260384.pdf
[356] General Regulations Of Environment In The GCC States 1997. P.1-2. https://www3.nd.edu/~ggoertz/rei/rei880/rei880.147tt1.pdf

human dignity.[357] At the same time, people are responsible for conserving the environment and enhancing it to benefit the future generation through sustainable development. Further, the responsibility to conserve the environment for natural resources to satisfy the development needs of the current and future generations is within the government authorities, public and private entities, and ordinary individuals.

Notably, safeguarding the environment from pollution and deterioration is cost-effective and more feasible than undoing the damage to the environment. Therefore, as a basic rule in the general principles in the GCC, environment protection considerations should be prioritized to prevent adverse effects from various activities like agricultural, construction, and industrial operations to the environment.[358] Additionally, responsible authorities, private agencies, and responsible individual actors should initiate environment assessment projects to prioritize environmental protection. The financing and lending institutions should be at the forefront of environmental protection by offering the required funds for environmental conservation projects.[359] Under Article 14, banking institutions can also contribute to environmental protection by considering compliance with environmental protection laws as the minimum condition for offering to lend for projects.

The best available technologies should be adopted and used in various facilities and environmental projects to control pollution and prevent environmental degradation. Under Article 6 of the General Principles, a licensing authority is mandated to ensure that new projects and any significant changes to the existing environmental projects apply advanced technology for pollution

[357] General Regulations of Environment In The GCC States 1997. P.1-2. http://www.gcc-sg.org/en-us/CognitiveSources/DigitalLibrary/Lists/DigitalLibrary/Environment/1274260384.pdf
[358] General Regulations of Environment In The GCC States 1997. P.1-2. http://www.gcc-sg.org/en-us/CognitiveSources/DigitalLibrary/Lists/DigitalLibrary/Environment/1274260384.pdf
[359] General Regulations of Environment In The GCC States 1997. P.7 https://www3.nd.edu/~ggoertz/rei/rei880/rei880.147tt1.pdf

control and prevention of environmental degradation. All the technologies used for environmental projects should comply with the environmental feasibility standards to prevent any adverse effects on the environment.[360] Additionally, the revival and development of effective traditional technologies should be undertaken within the framework.[361] Further, the licensing authority should establish standards that consider aspects like the project type and its age and any steps or required procedures to be followed in the project.

Another fundamental rule to be emphasized under the general principles is creating awareness and enhancing environmental education among persons and the community. Mass media and education curriculum that prioritizes the vitality of teaching a sense of responsibility should create awareness at the personal and collective level. The initiative is fundamental in environmental protection by preventing pollution and facilitating environmental responsibility among persons.

The GCC has made critical milestones concerning awareness creation. For example, the member states have developed robust awareness programs, including introducing environmental education at all levels of education.[362] Other programs encompass organizing forums, workshops, panels, and meeting sessions at national and regional levels. Further, the GCC has partnered with the Join Program Corporation for the GCC member states and private sector to produce over 30 TV episodes on environmental topics and hazards that threaten the environment. The program is

[360] General Regulations of Environment In The GCC States 1997. P.1-2. http://www.gcc-sg.org/en-us/CognitiveSources/DigitalLibrary/Lists/DigitalLibrary/Environment/1274260384.pdf
[361] General Regulations of Environment In The GCC States 1997. P.5. https://www3.nd.edu/~ggoertz/rei/rei880/rei880.147tt1.pdf
[362] GCC. Cooperation in the field of human and environment affairs. https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx

critical in awareness creation in the member states to enhance environmental protection by various parties.[363]

Furthermore, it is worth noting that the GCC member states have also created awareness through the Environmental Days like the Regional Environment Day, the Arab Environment Day, the International Environment Day, the International Day for Protecting the Ozone Layer, and the International Day for Biologic Diversity.[364] The programs continue to be instrumental to the GCC's efforts to create awareness on environmental protection.

Most importantly, the GCC States have incorporated virtual environment concepts into the education curricula to assist people in gaining values, skills, and facts required in understanding the relationships between human beings and the environment.[365] As a result, people and society can protect the natural resources and use the resources sustainably for the benefit of society. Further, the Ministers responsible for the environment among the GCC member states have resolved to organize Environment Week annually to foster environmental awareness and education.

Article 7 of the General Principles specifies the need for environmental supervisors.[366] Individuals in charge of any project whose activities may adversely impact the environment must appoint or designate a representative to ensure that all activities and operations comply with the environmental regulations. Article 19 of the General Principles provides the control of harmful activities that directly relate to the recycling and management of WEEE. A responsible authority

[363] Ibid.
[364] GCC. Cooperation in the field of human and environment affairs. https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx
[365] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx
[366] General Regulations of Environment in The GCC States 1997. P.5. http://www.gcc-sg.org/en-us/CognitiveSources/DigitalLibrary/Lists/DigitalLibrary/Environment/1274260384.pdf

among the GCC member states should take the necessary measures to avoid, prevent or limit damage to lower levels. Some of the prevention mechanisms to be adopted by responsible authorities include imposing a temporary or permanent ban on activities considered harmful to the environment, imposing restrictions on environmentally harmful activities to reduce damage, and imposing any other ban deemed necessary by the agency to protect the environment.[367] Under Article 20 of the General Principles, an environmental authority is also expected to inspect project facilities and request reports about activities with significant environmental impacts.

In any case of environmental regulation infringement, the responsible authority will ask the violators to provide detailed reports regarding the steps and actions underway to prevent a recurrence. In some extreme cases of environmental degradation, the concerned environmental authority among the GCC member states can ask an individual to remove any solid, liquid, or gaseous substances deemed to pose harm to the environment. Penalties are to be imposed against any person who violates environmental regulation.[368] The penalties may include suspension of project activities that fail to adhere to the environmental regulations until the concerned authority is convinced that adequate measures are in place to prevent further harm to the environment and that the violator is adhering to the environmental standards.

6.2.2 General Environment Protection Law (Muscat, 1995)

The General Environment Protection Law is a comprehensive legal framework that incorporates the fundamental principles for environment conservation and protection. The Supreme Council of the GCC adopted the regulatory framework in Muscat in 1995.[369] The law

[367] General Regulations of Environment in The GCC States 1997. P.10. http://www.gcc-sg.org/en-us/CognitiveSources/DigitalLibrary/Lists/DigitalLibrary/Environment/1274260384.pdf
[368] General Regulations of Environment in The GCC States 1997. P.9. http://www.gcc-sg.org/en-us/CognitiveSources/DigitalLibrary/Lists/DigitalLibrary/Environment/1274260384.pdf
[369] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx

speaks to most of the principles that have already been highlighted above. The law emphasizes the need to ensure that projects comply with the set procedures and prevent pollution of the environment.

6.2.3 Common Law for the Environmental Assessment of Projects (Muscat, 1995)

The law is crucial in monitoring the environmental effects of various projects to prevent their negative impacts on the environment, natural resources, and development.[370] The Common Law for Environmental Assessment of Projects was adopted by Supreme Council (Muscat, 1995). Environmental impact assessment (EIA) is essential in preventing environmental harm. This law thus incorporates the preventive principle discussed to a great length in Chapter 3 of this research. Notably, managing hazardous wastes and chemicals requires vigilance during the project implementation phase and continued assessment. This law offers a general guideline to GCC members when carrying out projects with adverse environmental impacts.

6.2.4 Common Law for Waste Management (Kuwait, 1997)

The law aims at safeguarding human health and the environment from the hazards resulting from solid and toxic waste. The legal framework promotes a sound waste management system to protect human beings and the environment from harmful substances.[371] The law was adopted by the Supreme Council.

[370] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx

[371] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx

6.2.5 Common Law for the Management of Hazardous Chemicals (Muscat, 2001)

The law seeks to control the hazardous chemicals handling in the GCC member states.[372] The GCC Supreme Council adopted it in Muscat, 2001. It is one of the laws that apply to e-wastes since electricals and electronic equipment also contain hazardous chemicals and metals.

6.2.6 Coordination of procedures among the Member States for trans-border handling of hazardous waste for processing, recycling, or disposal, 1997

The procedures seek to enable safe and trans-border management of hazardous wastes to facilitate their processing or recycling. Member states are expected to use their facilities appropriately to recycle and process hazardous waste to prevent or reduce potential environmental impacts.[373] The Supreme Council adopted the safe handling of waste procedures in Muscat in 1997.

6.2.7 Common Law for the Management of Healthcare Waste (Muscat, 2001)

The purpose of the law is to develop a robust mechanism for controlling the production, sorting, storage, and handling, processing of healthcare wastes, and ensuring their safe disposal among the GCC member countries.[374] The Supreme Council of the GCC adopted the law in Muscat, 2001. Some of the healthcare wastes form part of e-wastes, and the law is equally relevant to the handling of e-waste.

[372] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx
[373] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx
[374] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx

6.2.8 Common Reference Law for Controlling the Ozone Depleting Materials (Abu Dhabi, 2005)

The law seeks to end the utilization of Ozone-depleting materials and replace them with safe alternatives based on the Montreal Protocol and amendments.[375] It was adopted in Abu Dhabi in 2005 by the Supreme Council. It is vital to understand the components of electronic waste that may contribute to the depletion of the Ozone layer, such as the gases in refrigerators and cooling items.

6.2.9 Unified Law (Regulation) of the Gulf Cooperation Council (GCC) for the Arab States on the Control of Substances that Deplete the Ozone Layer

The law has 19 articles and seeks to eliminate ozone-depleting substances and replace them with safe alternatives based on the Montreal Protocol and amendments, just like the Common reference law that has already been discussed above. Further, the law regulates the importation, exporting, trading, and recycling and the use of controlled substances and appliances, equipment, and products that are likely to deplete the ozone layer based on the Montreal Protocol.[376] The law requires the GCC member states to draw up plans and execute strategies and programs to qualify sectors that rely on the controlled materials and assist them in adhering to safe practices during the maintenance operations and conversion to appropriate alternatives. The law also seeks to facilitate the exchange of information and data among the GCC member countries to trade controlled substances.

Article 3 of the Unified Law (Regulation) of the GCC on the Control of Substances that Deplete the Ozone Layer requires that a competent authority in every member state should provide a comprehensive list of the controlled substances according to the state's obligations about the

[375] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx

[376] Unified Law (Regulation) of the Gulf Cooperation Council (GCC) for the Arab States on the Control of Substances that Deplete the Ozone Layer. http://www.fao.org/faolex/results/details/en/c/LEX-FAOC175545/

Montreal Protocol.[377] The law applies to WEEE management since it prohibits importing, manufacturing, and utilizing the controlled substances, the used and new appliances and equipment deemed harmful to the ozone layer. As a result, the GCC states are expected to exchange data concerning controlled substances and establish rules and regulations for trading the substances.

6.3 National Environmental Laws, Regulations and Edicts Applicable to E-Waste

6.3.1 Bahrain

Bahrain remains one of the largest per capita waste generators globally, estimated at 1.7 kg/capita /day. In 2015 alone, the country generated over 1.2 million tons of solid wastes. The most worrying concern is that Bahrain has only one landfill that takes about 700 acres and is expected to fill in the next few years despite the high waste generation.[378] However, Bahrain is taking robust measures to manage e-waste. Part of the waste management efforts has focused on e-waste recycling in partnership with the Supreme Council for Environment. There are various recycling initiatives initiated through a public-private partnership. Bahrain also seeks to raise awareness concerning electronic waste and enhance effective recycling of end-of-life electronics to ensure their disposal in an environmentally friendly manner.[379] To ensure environmental sustainability, Bahrain has established a program to raise awareness on recycling electronic wastes in ways that protect the environment.

Despite the numerous efforts by Bahrain to promote proper e-waste management, the GCC state has not developed comprehensive laws on e-waste management. However, the country has some of the most advanced bylaws related to waste management policies in the Middle East and

[377] Unified Law (Regulation) of the Gulf Cooperation Council (GCC) for the Arab States on the Control of Substances that Deplete the Ozone Layer. http://www.fao.org/faolex/results/details/en/c/LEX-FAOC175545/
[378] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.4
[379] Bahrain Bourse. "E-Waste." https://bahrainbourse.com/ewaste

North Africa (MENA) region.[380] Notably, Bahrain prioritizes e-waste management due to its limited land resources, making landfills unfeasible and costly. Additionally, Bahrain has established legislative decrees and ministerial orders that govern the protection of the environment from hazardous substances.

6.3.1.1 Legislative Decree No.21 of 1996

The Legislative Decree No.21 of 1996 in Bahrain relates to the protection of the environment. The legislation is not specifically directed at e-waste management but seeks to safeguard the environment from polluting sources, including e-waste.[381] Further, the law aims at halting environmental degradation by creating effective plans and policies to conserve it from adverse effects resulting from activities that cause damage to human health, marine life, wildlife, and other natural resources. The Legislative Decree No.21 of 1996 requires establishing and implementing plans and policies and adopting the necessary procedures to address environmental pollution from various sources, including the e-wastes.

Further, the Legislative Decree No. (21) of 1996 on the environment offers a comprehensive regulatory framework for managing hazardous wastes. The provisions of the law are designed to protect sources and polluting factors to stop environmental degradation. Notably, Article 14 of the Legislative Decree No. 21 prohibits any trading of hazardous substances and wastes without the approval of the environmental authority.[382] Further, Article 15 of the Legislative Decree requires that persons handling hazardous materials in the gaseous, liquid, or solid form comply with the necessary precautions and requirements to avoid environmental

[380] Alameer, Hasan. "Assessment and evaluation of waste electric and electronics disposal system in the middle east." *European Scientific Journal* 10, no. 12 (2014). P.382.
[381] Kingdom of Bahrain. The Supreme Council for Environment. "Bahrain National Profile to Assess the National Infrastructure for Chemical Safety." P.59 https://cwm.unitar.org/national-profiles/publications/cw/np/np_pdf/Bahrain_National_Profile_update.pdf
[382] Bahrain Legislative Decree No. (21) for the year 1996 on the (environment (21/1996)). P.3. https://s3.amazonaws.com/rgi-documents/54824f0a8c2002b0a91d6ea7993f1996b6436d43.pdf

damage. The waste records and their disposal procedures must be kept and shared with the Minister of Housing, Municipalities, and Environment.[383] Article 16 of the Legislative Decree No. 21 also applies to the management of electronic wastes in Bahrain. The law requires necessary precautions and measures to avoid leaking or emitting polluting substances and agents within the permissible limits as determined by the responsible authority.

6.3.1.2 Ministerial Order No. 3 of 2006

Ministerial Order No. 3 of 2006 relating to managing hazardous wastes also applies to the e-wastes. Notably, the Ministerial Order creates an effective monitoring and control system for generating, storing, transporting, and treating hazardous waste.[384] Further, Order No.3 is suitable for exercising control of hazardous wastes and preventing their adverse effects on the environment and the consequent damage to public health. The Ministerial Order No. 3 of 2006 also applies to the management of e-waste in Bahrain.[385] The Order focuses on managing chemicals by establishing a proper monitoring and management system for hazardous chemicals. The law seeks to eliminate or limit the spread of harmful chemicals to the environment. Improper waste management and disposal have potential adverse effects on the soil, water, and air. As a result, the country has established a multi-disciplinary committee to facilitate ecologically sound waste management through a robust national strategy for executing Agenda 21.[386]

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[383] Bahrain Legislative Decree No. (21) for the year 1996 on the (environment (21/1996)). P.3. https://s3.amazonaws.com/rgi-documents/54824f0a8c2002b0a91d6ea7993f1996b6436d43.pdf

[384] Kingdom of Bahrain. "The Supreme Council for Environment. Bahrain National Profile to Assess the National Infrastructure for Chemical Safety." p.60 https://cwm.unitar.org/national-profiles/publications/cw/np/np_pdf/Bahrain_National_Profile_update.pdf

[385] Kingdom of Bahrain. "The Supreme Council for Environment. Bahrain National Profile to Assess the National Infrastructure for Chemical Safety." p.60 https://cwm.unitar.org/national-profiles/publications/cw/np/np_pdf/Bahrain_National_Profile_update.pdf

[386] Kingdom of Bahrain. The Supreme Council for Environment. "Bahrain National Profile to Assess the National Infrastructure for Chemical Safety." p.41 https://cwm.unitar.org/national-profiles/publications/cw/np/np_pdf/Bahrain_National_Profile_update.pdf

6.3.2 Kuwait

Kuwait has established about 18 landfills, of which 14 have been closed. The landfills cause adverse health and environmental effects because of toxic gases and substances from the dumpsites.[387] It is estimated that Kuwait generates an average of 1.4 kg per person of wastes daily.[388] It was projected that the waste generation would reach 2.51 million tons by 2020. Thus, solid waste management remains a concern in Kuwait as the untreated wastes taken to the landfills pose severe environmental and health hazards.

6.3.2.1 Environmental Protection Law No.42 of 2014

Kuwait established the Environmental Public Authority (EPA) in 1995 to oversee the management of wastes.[389] Further, there is a comprehensive legal framework that regulates the management of waste, including WEEE. Notably, Article 7, Section 11 of the Environmental Protection Law No.42 of 2014 provides the establishment and execution of comprehensive national programs for a regular survey and monitoring of environmental standards and indicators in the environmental sectors.[390] Additionally, the Environmental Protection Authority has plans to implement surveys and monitor environmental standards and create a comprehensive waste management database in the GCC state.

Under Article 51 of the Environment Protection Law No. 42 of 2014, the Environment Public Authority is mandated to create, develop and update the country's framework for regular monitoring and control of air quality. All government authorities and private sector players must

[387] Alsulaili, Abdalrahman, Bazza AlSager, Hessa Albanwan, Aisha Almeer, and Latifa AlEssa. "An integrated solid waste management system in Kuwait." In *5th international conference on environmental science and technology*, vol. 69, no. 12, pp. 54-59. Singapore: IACSIT Press, 2014. P.55

[388] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.4

[389] Mihai, Florin-Constantin, Maria-Grazie Gnoni, Christia Meidiana, Chukwunonye Ezeah, and Valerio Elia. "Waste electrical and electronic equipment (WEEE): flows, quantities, and management—a global scenario." In *Electronic waste management and treatment technology*, pp. 1-34. Butterworth-Heinemann, 2019. P.23. https://hal.archives-ouvertes.fr/hal-02276468/document

[390] EPA. "Wasters." https://epa.org.kw/en-us/Waste

comply with the legislation by creating their monitoring and control systems and integrating them with the EPA as provided in the Executive Bylaw of the Environment Protection Law No. 42 of 2014.[391] Article 52 of the law further provides that the government agencies and private sector players ensure that their activities and installations avoid emitting or leaking pollutants beyond the permitted limits.

Article 55 of Law No. 42 of 2014 applies to the recycling of e-waste using incinerators. The law prohibits any establishment of installations that emanate noise and cause harm to the environment. The Executive Bylaw of the law mandates the Environmental Public Authority to ensure proper enforcement of noise-limiting systems around human populations.[392] Therefore, the use of incinerators for recycling electronic wastes must be undertaken under controlled conditions that limit noise pollution to ensure that such e-recycling installation adheres to the provisions of the Environmental Protection Law No. 42 of 2014.

6.3.3 Oman

Waste management in the Sultanate of Oman remains a critical concern. It is estimated that Oman generates 1.7 million tons of wastes every year. The average per capita waste generation in Oman is 1.2 kg per individual daily.[393] Notably, Oman lacks a robust e-waste recycling program despite the high e-waste generation. As a result, most of its wastes are sent to dumpsites and landfills. However, the country has realized the need to develop a comprehensive legal and regulatory framework to guide the management of electronic wastes.

[391] Law No. 42 of 2014 Promulgating The Environment Protection Law.p.34 http://extwprlegs1.fao.org/docs/pdf/kuw142030E.pdf
[392] Law No. 42 of 2014 Promulgating The Environment Protection Law.p.36 http://extwprlegs1.fao.org/docs/pdf/kuw142030E.pdf
[393] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.5

6.3.3.1 Basic Law of Oman (RD 101-1996)

The Basic Law of Oman (RD 101-1996), regarded as Oman's constitution, provides that environmental protection and pollution prevention is a social principle and the state's responsibility. However, there is no specific legal framework for regulating the management of electronic wastes. The existing law operates for all types of wastes generated in the Sultanate of Oman.

6.3.3.2 Law of Environment and Prevention of Pollution (RD 114-2001)

Notably, the environmental's fundamental legislative framework is the Law of Environment and Prevention of Pollution (RD 114-2001).[394] The law creates strict penalties for releasing pollutants and discharging wastes inland and Oman's maritime territory. Article 7 of the law provides that using Oman's environment to dispose of environmental pollutants in quantities and types that cause adverse impacts on the environment is prohibited. Thus, no pollutant should be disposed of in the environment unless the stipulated regulations and conditions are met as determined by the minister. Additionally, Article 10 of the law requires waste generators to take appropriate measures and adopt advanced technologies that the ministry and other relevant authorities approve to reduce the generation of wastes.[395] Further, manufacturers are required to utilize clean production techniques to mitigate environmental pollution and conserve natural resources.

Article 41 stipulates the penalties that waste generators may face. Any person that causes harm to the environment is required to undertake its removal and reinstate the environmental status.[396] Other additional payments such as compensation may be required for waste generators

[394] Sustainable Oman. "Legislation and regulations." https://sustainableoman.com/omani-laws/
[395] Royal Decree No. 114/2001 Issuing The Law On Conservation Of The Environment And Prevention Of Pollution. p. 13. http://extwprlegs1.fao.org/docs/pdf/oma98254E.pdf
[396] Royal Decree No. 114/2001 Issuing the Law On Conservation Of The Environment And Prevention Of Pollution http://extwprlegs1.fao.org/docs/pdf/oma98254E.pdf p.14

that fail to handle their wastes safely. Further, the minister is expected to issue administrative and penal punishments for violating the environmental laws and regulations relating to waste management.

6.3.4 Qatar

Qatar is one of the world's fastest-growing economies. The steady economic growth has fueled annual waste generation. Currently, Qatar is estimated to generate 2.5 million tons of wastes yearly.[397] The daily per capita waste generation is 1.8kg. Qatar's primary waste disposal mechanism is landfilling despite the high waste generation resulting from constant economic growth. The gulf state has only three landfills. However, Qatar is currently emphasizing its waste management initiatives on reducing, recycling, and minimizing wastes.[398] Comprehensive waste management is being developed to attain a 38% recycling and minimize per capita waste generation.

6.3.4.1 Law No.30 of 2002

The environmental legal framework that applies to managing all wastes, including e-waste in the gulf state, is Law No.30 of 2002 that promulgated the Law of the Environment Protection. Article 25 prohibits establishing projects to treat hazardous wastes unless licensed by the Competent Administrative Authority and the Council.[399] Therefore, any treatment of e-wastes must be undertaken after formal approval by the responsible authority. Article 25 also prohibits any disposal of hazardous wastes without meeting the terms and conditions determined by the Executive Regulation. The Council is mandated to work with other responsible administrative

[397] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.6
[398] Alameer, Hasan. "Assessment and evaluation of waste electric and electronics disposal system in the middle east." *European Scientific Journal* 10, no. 12 (2014). P.383.
[399] Law No. 30 of 2002 promulgating the law of the environment protection. https://www.almeezan.qa/LawView.aspx?opt&LawID=4114&language=en

authorities to publish a comprehensive table of hazardous waste, locations, and conditions to be met for safe disposal.

Article 26 of Law No.30 of 2002 stipulates that a person shall not import, handle or transport hazardous wastes without the approval of the responsible government authority.[400] Thus, any handling, transporting, or importation of e-waste must be undertaken by any party only after getting approval from competent authority with the state. Most importantly, Article 27 of the law requires all persons in charge of the generation, handling, and transportation of hazardous wastes in gaseous, liquid, or solid form to take appropriate precautions to mitigate any harm to the environment.[401] Article 32 of Law No.30 of 2002 further applies to the management of e-waste by prohibiting any discharge, treatment, and incineration of solid wastes except for designated locations away from residential, industrial, and water sources.

6.3.5 Saudi Arabia

6.3.5.1 General Environmental Regulation, Council of Ministers Resolution No 193, 2002

The Kingdom of Saudi is the largest in GCC countries, with a waste generation of 15 million tons yearly. The Kingdom practices recycling at a rate of 10-15% while other wastes are collected from personal or community garbage bins for disposal into landfills.[402] The first comprehensive national environmental law in Saudi Arabia is the General Environmental Regulation, Council of Ministers Resolution No 193, enacted in September 2001.[403] The legislation came to force in 2001, and the implementing rules were established in 2003. Further,

[400] Law No. 30 of 2002 promulgating the law of the environment protection. https://www.almeezan.qa/LawView.aspx?opt&LawID=4114&language=en
[401] Law No. 30 of 2002 promulgating the law of the environment protection. https://www.almeezan.qa/LawView.aspx?opt&LawID=4114&language=en
[402] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.5
[403] Saudi Legal. "Environmental laws." https://www.saudilegal.com/saudi-law-overview/environmental-laws

the Environment Regulation, Royal Decree No M/165 of Dhul Qada 1441 Hejra came to force in January 2021.

The Presidency of Meteorology and Environment under the Ministry of Defense is responsible for supervising environmental affairs in the Kingdom and issuing environmental licenses. The Saudi Environmental Regulations and its Rules of Implementation focus on improving balanced environmental activities, conserving the environment, and enhancing environmental awareness in society.[404] Notably, the rules of execution of the environmental regulations seek to establish the procedures, ground, and basis for regulating all actions with impacts on the environment and coordinating response actions, pollution control, and safeguarding the natural resources. The Environmental Regulations and Rules are fundamental in regulating the management of e-waste in the Kingdom of Saudi Arabia as they specify the procedures and principles for regulating all activities with environmental impacts. Further, the regulations and rules incorporate all the types of environmental violations and the necessary penalties to safeguard human health and the environment from pollution.

Article 13 of the General Rules and Regulations on the Environment directly applies to the management of e-waste. The law requires that all individuals involved in productive activities, services, and other activities take appropriate measures to comply with the regulations. Additionally, every person shall prevent direct or indirect contamination of water sources, air, and ground by solid or liquid wastes.[405] Further, state-of-the-art technology should be used together with other necessary means to prevent pollution of surface, ground, and water sources.

[404] General Environmental Regulations And Rules for Implementation. P.6. https://elaw.org/system/files/attachments/publicresource/saudiarabia.General%20Environmental%20Regulations.pdf
[405] General Environmental Regulations And Rules for Implementation. P.32. https://elaw.org/system/files/attachments/publicresource/saudiarabia.General%20Environmental%20Regulations.pdf

Further, Article 13 directs those individuals involved in waste generation activities to eliminate all forms of contamination on soil, air, and water and absorb all the costs of prevention, control, and pollution minimization. Persons are required to prevent discharge in any quantity of hazardous solid or liquid wastes, elements, organic or inorganic compounds to the environment. Therefore, the handling of e-waste must follow the regulatory standards set out in Article 13 to protect the environment from contamination with hazardous electronic wastes.[406] Additionally, Article 13(3) (2) directly applies to the handling of e-waste by requiring the use of technologies and equipment that generate low noise levels to achieve the allowable noise levels. Thus, the waste recycling technologies like incineration should be advanced to facilitate the attainment of allowable limit noise when recycling solid e-wastes.

Article 14 of the General Environmental Regulations prohibits any hazardous, toxic, or radioactive wastes from entering Saudi Arabia and territorial waters. All agencies and individuals must adhere to the regulatory standards, guidelines, and policies related to the production, exchange, treatment, storage, transportation, and recycling of hazardous wastes. Further, persons responsible for producing, transporting, recycling, treating, and disposing of hazardous, toxic, and radioactive materials should adhere to the requirements of licenses issued by the Competent Agency.[407] Therefore, the General Environment Regulations strictly regulate the transportation, storage, recycling, and treatment of hazardous e-waste.

6.3.5.2 Draft Waste Management Regulation, 2020

Saudi Arabia proposed new Waste Management Regulation through its Ministry of Environment, Water, and Agriculture. The draft sought to facilitate integrated waste management,

[406] General Environmental Regulations And Rules for Implementation. P.32
https://elaw.org/system/files/attachments/publicresource/saudiarabia.General%20Environmental%20Regulations.pdf

[407] General Environmental Regulations And Rules for Implementation. P.32.
https://elaw.org/system/files/attachments/publicresource/saudiarabia.General%20Environmental%20Regulations.pdf

minimizing waste production and managing all operations, including sorting, storing, collecting, transporting, and recycling recyclable wastes. The draft regulatory policy for waste management covers WEEE, waste batteries, hazardous waste, industrial waste, and municipal solid waste. Most importantly, the draft regulation will offer a framework for managing electronic waste. Currently, the regulation of e-waste management is under the Management of Hazardous Waste Regulation 1423/2001.[408] Thus, the draft is fundamental in e-waste management as it offers the general rules for managing e-waste.

6.3.6 United Arab Emirates

6.3.6.1 Federal Law No. 24 of 1999 for the protection and development of the environment (Environmental Law)

Federal Law No. 24 of 1999 offers a robust regulatory framework for environmental protection in the United Arab Emirates. Article 9 of the law provides that all responsible individuals for planning, economic, and construction development shall take the necessary measures to safeguard the environment, control pollution, and rationalize the available resources when implementing their projects.[409] Further, Article 48 directly applies to the management of e-waste by requiring that agencies and individuals must ensure that air pollutants do not exceed the allowable limits as determined by the Executive Order. Article 50 of the law further prohibits throwing, treating, or burning residue and solid wastes unless the practices are undertaken in designated places far from residential, industrial, and agricultural locations.[410] Thus, the handling of e-waste must adhere to Article 50 to protect the environment from pollution.

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[408] Compliance & risks. Saudi Arabia proposes draft Waste Management Regulation. http://blog.complianceandrisks.com/news-resources/saudi-arabia-proposes-draft-waste-management-regulation

[409] Federal Law No. 24 of 1999 for the protection and development of the environment. P.11. https://www.dewa.gov.ae/~/media/Files/About%20DEWA/Legislations/English/Federal%20Law%20No24%20of%201999%20on%20Enviroment%20Protection.ashx

[410] Federal Law No. 24 of 1999 for the protection and development of the environment. P.22. https://www.dewa.gov.ae/~/media/Files/About%20DEWA/Legislations/English/Federal%20Law%20No24%20of%201999%20on%20Enviroment%20Protection.ashx

6.3.6.2 Federal Law No. 12 of 2018 on the Integrated Waste Management

Federal Law No. 12 of 2018 aims to regulate the waste management process and integrate the techniques and methods of safe disposal. The law promotes the adoption and use of best practices to safeguard the environment and reduce harm to human health.[411] The law applies to the entire waste management cycle from waste generation, separation, collection, transport, storage, reuse, recycling, treatment, and disposal in the state.

Article 6 of Federal Law No. 12 of 2018 applies to e-waste management since it allows the Ministry and Competent Agency to prohibit various waste-producing materials. The introduction or importation of materials that are difficult to dispose of and whose disposal is hazardous to the environment is prohibited. Additionally, manufacturers may be prohibited from using or importing waste-producing materials whose disposal may cause environmental harm. Therefore, manufacturers of electrical and electronic equipment and devices in the UAE may be prohibited from using or importing materials that can be hazardous to the environment upon their disposal.

Further, Article 7 of the law authorizes the ministry in coordination with a Competent Authority to require various parties to reuse various types of wastes if the initiative has less adverse impacts on the environment than their disposal.[412] Article 8 of the Federal Law provides rules for the disposal of waste. No person is allowed to dispose of, bury or burn waste in open fields, roads, waterways unless in designated locations for disposing wastes. Thus, waste can only be disposed of in landfills that a Competent Authority approves. Additionally, Article 13 of the law regulates the management of hazardous waste.[413] A Competent Authority is required to manage hazardous waste following environmental protection, health, and safety standards. The responsible authority must establish a robust initiative to monitor hazardous waste and its impacts on the environment.

[411] Federal Law No. 12 of 2018 on the integrated waste management. p.2.
[412] Federal Law No. 12 of 2018 on the integrated waste management. p.3.
[413] Federal Law No. 12 of 2018 on the integrated waste management. p.4.

6.3.6.3 Law No. 21 of 2005 for Waste Management (Abu Dhabi)

Law No. 21 of 2005 for waste management specifies the responsibilities of various parties involved in waste management in Abu Dhabi. For example, a Competent Authority is mandated to enhance waste management in the Emirate through interventions such as reducing wastes, recycling and reusing generated waste, and offering treatment solutions for various types of wastes. Further, a Competent Authority is to establish the priorities and best practices for waste disposal. The authority must also coordinate with all other relevant parties to ensure compliance with the waste management regulations.[414] Concerned parties in waste management are mandated by Article 3 to promote efficient waste management within the waste generating sectors by offering adequate and integrated systems and solutions for managing, storing, treating, and disposing of wastes.

Article 5 of Law No. 21 of 2005 applies to e-waste management in Abu Dhabi by stipulating the responsibilities of waste generators. Specifically, waste generators are mandated to reduce waste generation by executing regulations, methods, and approaches approved in the Emirate to classify, sort, reuse, and recycle waste.[415] Further, waste generators are required to classify waste into hazardous and non-hazardous as determined by the approved guidelines. Therefore, all the parties involved in waste management have designated roles to reduce environmental pollution from generated waste.

6.3.6.4 Decree No. 42 of 2009 Concerning the Comprehensive Environmental Health and Safety Management System (EHSMS) (Abu Dhabi)

The Decree seeks to implement the Environment, Health, and Safety Management System in Abu Dhabi. It offers an integrated mechanism for implementing the laws applicable to the environment, health, and safety, safeguarding human health, and conserving the environment and

[414] Law No. (21) Of 2005 for waste management in the Emirate of Abu Dhabi. P.2
[415] Law No. (21) Of 2005 for waste management in the Emirate of Abu Dhabi. P.5

natural resources.[416] Notably, Article 8 of the Decree provides that all entities establish and execute EHSMS within their scope of activities to safeguard the environment from adverse impacts caused by the activities. Further, entities should undertake yearly audits on their EHSMS to comply with the Emirate's EHSMS.

Conclusion

This chapter has discussed the international conventions regarding e-waste management and the national laws of GCC countries relating to e-waste regulation. Basel Convention has been domesticated in Bahrain through the Legislative Decree No.21 of 1996. The Decree is instrumental in regulating the transboundary movement of hazardous wastes from Bahrain to other states. Other countries that have domesticated the Basel Convention are Qatar, Oman, Saudi Arabia and the UAE. Bahrain has also domesticated the Stockholm Convention into its national environmental law through the Ministerial Order No.4 of 2006. The legislation creates adequate monitoring and management system for handling hazardous chemicals.

Similarly, Kuwait has integrated the Stockholm Convention into its national legislation through Law No. 42 of 2014. However, Qatar, Saudi Arabia and UAE Oman have not domesticated the Stockholm Convention. Notably, Qatar has domesticated the Montreal Protocol into its national environmental law through Law No.21 of 2007 under Decree No.23 of 1999. Bahrain has domesticated the Rotterdam Convention by establishing Law 14/2012 that promotes shared responsibilities on importing hazardous chemicals. However, other GCC countries have not implemented the Rotterdam Convention rules into their national environmental laws despite ratifying the Convention.

[416] Decree No. (42) Of 2009 concerning Abu Dhabi EHSMS. P.3

This chapter has also discussed the national environmental laws, regulations, and mandates applicable to e-waste management in the GCC. Saudi Arabia has a comprehensive national regulatory framework under the General Rules and Regulations on the Environment. Saudi Arabia has also proposed a Waste Management Regulation through the Ministry of Environment, Water and Agriculture to promote integrated waste management. The regulatory draft covers e-wastes, hazardous wastes, MSW, and waste batteries. Kuwait has created the Environment Protection Law No. 42 of 2014 that regulates the management of e-waste. Oman used the Law of Environment and Prevention of Pollution (RD 114-2001) that creates penalties for releasing and discharging wastes within Oman and its maritime territory. Qatar applies Law No.30 of 2002 that focuses on environmental protection.

The United Arab Emirates has equally established sufficient legal safeguards to regulate e-wastes. Federal Law No. 12 of 2018 seeks to regulate the country's waste management process and integrate methods and techniques of safe disposal. Other regulations include the Federal Law No. 24 of 1999, Decree No. 42 of 2009 Concerning the Comprehensive Environmental Health and Safety Management System (EHSMS) (Abu Dhabi) and Law No. 21 of 2005 for Waste Management (Abu Dhabi). Therefore, the UAE and Saudi Arabia have the most comprehensive environmental laws to ensure appropriate management of e-waste in the Gulf. The next chapter will analyze the status of e-waste generation, quantities, and flows of e-wastes within the GCC countries. The chapter will offer insights into the e-waste management within the GCC with a focus on every state.

CHAPTER SEVEN

TRENDS IN E-WASTE PRODUCTION, QUANTITIES, FLOWS, AND MANAGEMENT WITHIN THE GCC MEMBER STATES

7.0 Introduction

The Gulf Cooperation Council states including Qatar, Bahrain, Oman, Saudi Arabia, and the United Arab Emirates have experienced a rapid surge in population growth and economic development. The rise in population growth and economic development has been characterized by e-waste challenges that pose health and environmental sustainability risks among the GCC countries. Some of the e-wastes commonly found in the GCC countries are cooling and freezing equipment, IT and telecommunication equipment, screens and monitors, lamps, and other small and large electrical equipment.[417] E-waste is often classified as hazardous waste because of harmful substances such as lead, mercury, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants. However, e-waste management remains a significant challenge among the GCC countries despite its harmful effects on the environment and human health.[418] This chapter analyzes the status of e-waste generation, quantities, and flows within the GCC. The chapter further discusses the management of e-waste in the GCC countries.

7.1 E-WASTE GENERATION, QUANTITIES, AND FLOWS WITHIN THE GCC

7.1.1 Generation of E-Waste in Bahrain

Bahrain is currently one of the largest per capita e-waste generators across the globe. Further, the country grapples with waste management challenges emerging from the high population growth rate, rapid industrialization, limited land resources, and poor awareness among the public.[419] Notably, Bahrain has the highest population density in the GCC, with 900 persons

[417] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.3
[418] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016.
[419] Zafar, Salman. "Solid waste management in Bahrain." (2017). https://www.bioenergyconsult.com/tag/bahrain/

per square kilometer. Additionally, Bahrain's per capita waste generation is considerably high at 1.67-1.8 kg per day.[420] The rapid use of consumer electronics in Bahrain, particularly mobile phones and computers, further worsens the e-waste generation problem in the fast-growing GCC country. For instance, the replacement period for consumer electronics is only 18-24 months.[421] Thus, the trend will see a rapid rise in electronic wastes in the future, creating adverse environmental impacts if prompt actions are not taken to address the problem.

In 2015 alone, Bahrain generated 1.2 million tons of solid waste yearly. Further, the daily waste generation in the Gulf state is more than 4500 tons. Besides, a 2020 report by the Global W-waste Monitor noted that Bahrain generated 24kt of e-waste in 2019, equivalent to 15.9 kg per capita, as shown in **Figure 7.1.: E-waste Production Levels**.[422] Despite the high waste generation, the country has only one landfill that takes about 700 acres and is anticipated to reach total capacity in the future.

Further, the proximity of the Askar landfill to the urban settlements has become a critical environmental and health concern. Notably, Bahrain's rising accumulation of waste is anticipated to cause severe effects on air, soil, and groundwater.[423] The informal sector players are the critical collectors of the recyclables for recycling within the nations. The figure below shows the e-waste production levels in GCC countries as of 2014, 2016, and 2019.

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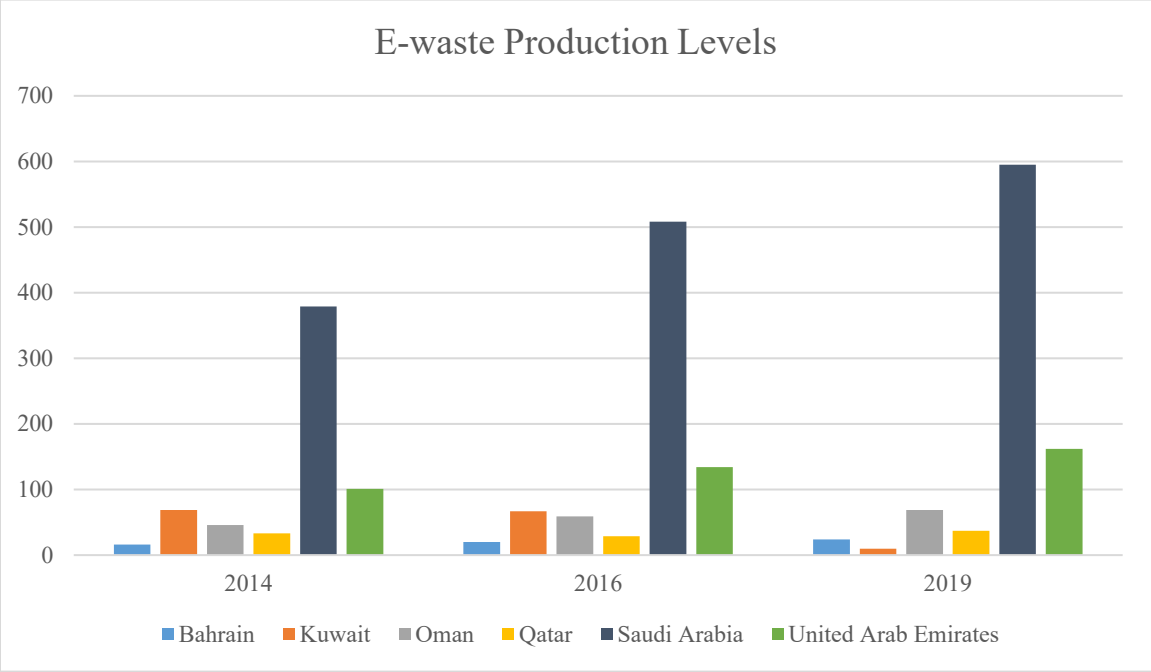
[420] Indrupati, Joel, and Tara Henari. "Consumer Behaviour in E-Waste Disposal-A Case for Setting up an E-Waste Collection and Recycling Facility in Bahrain." P.4 https://www.researchgate.net/publication/316623122_Consumer_Behaviour_in_E-Waste_Disposal_-_A_Case_for_Setting_up_an_E-Waste_Collection_and_Recycling_Facility_in_Bahrain

[421] Indrupati, Joel, and Tara Henari. "Consumer Behaviour in E-Waste Disposal-A Case for Setting up an E-Waste Collection and Recycling Facility in Bahrain." P.3 https://www.researchgate.net/publication/316623122_Consumer_Behaviour_in_E-Waste_Disposal_-_A_Case_for_Setting_up_an_E-Waste_Collection_and_Recycling_Facility_in_Bahrain

[422] Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam. https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/Global-Ewaste-Monitor-2020.aspx

[423] Zafar, Salman. "Solid waste management in Bahrain." (2017). https://www.bioenergyconsult.com/tag/bahrain/

Figure 7.1.: E-waste Production Levels



7.1.2 Generation of E-Waste in Kuwait

Kuwait has a high level of waste generation per capita, according to a World Bank study.[424] The solid waste production in Kuwait is 1.4 kg per capita daily, while the yearly total waste generation is 2 million tons. Additionally, the annual waste generation was forecasted to reach 2.51 million tons in Kuwait by the end of 2020. The waste comprises 50% organic waste, 21% paper, 13% plastic, and 15% others, including electronic waste.[425] As of 2020, the Global E-waste Monitor report noted that Kuwait produced 74 kt of e-waste in 2019, which translates to 15.8 kg

[424] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.3 https://www.researchgate.net/publication/309537926_Electronic_Waste_Management_and_security_in_GCC_Countries_A_Growing_Challenge

[425] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.3 https://www.researchgate.net/publication/309537926_Electronic_Waste_Management_and_security_in_GCC_Countries_A_Growing_Challenge

per capita.[426] The figure below shows the statistics of e-waste generation in 2019 as reported by the Global E-waste report.

Figure 7.2.: GCC E-waste Generation in 2019

Country	E-waste generated (kt) (2019)	E-waste generated (kg per capita) (2019)	E-waste documented to be collected and recycled (kt)	National e-waste legislation/policy or regulation in place
Bahrain	24	15.9	N/A	No
Kuwait	10	1.5	N/A	No
Oman	69	15.8	N/A	No
Qatar	37	13.6	N/A	No
Saudi Arabia	595	17.6	N/A	No
United Arab Emirates	162	15.0	N/A	No

Source: Forti et al.: *The Global E-waste Monitor 2020*[427]

Notably, e-waste is the fastest growing waste stream in Kuwait that has reported a 5-7% annual increase because of the increased obsolescence of technologies and the rapid advancement of technology.[428] The e-waste generation is anticipated to reach 100000 tons per year compared to the global 50 million tons estimates.[429] Additionally, e-waste is considered the most harmful waste stream in Kuwait because of carcinogenic and toxic materials that contaminate groundwater and cause irreversible damage to the environment.

[426] Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam. https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/Global-Ewaste-Monitor-2020.aspx

[427] Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam. https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/Global-Ewaste-Monitor-2020.aspx

[428] Environserve. https://enviroservekw.com/

[429] Environserve. https://enviroservekw.com/

Landfill remains the primary waste disposal method in Kuwait, covering more than 5433 square kilometers.[430] However, the landfills are mostly dumpsites rather than appropriately engineered landfill sites. As a result, the limited engineered landfills pose severe risks to the environment and health due to toxic gases like methane, carbon dioxide, and other hazardous wastes. Furthermore, the existing landfills are located near urban settings and can adversely affect population health and cause pollution on groundwater.

7.1.3 Generation of E-Waste in Oman

Oman produces over 1.7 million Municipal Solid Waste (MSW) every year. With over 4.1 million population, the per capita waste generation is more than 1.2 kg per day. Notably, by 2020, Oman is anticipated to generate 4.6 million tons of waste per year.[431] Like other GCC nations, Oman has seen a rise in e-waste as electronic items like laptops, cellphones, and other portable electronic devices are increasingly being replaced by new models.

The Sultanate of Oman's population comprises 50% of the younger generation. As a result, 65% of Oman's population have adopted smartphones, leading to the surge in mobile phone e-wastes. Further, the Oman Information Technology Authority estimates that over 80% of households have a desktop or laptop.[432] The demographic characteristics and technology trends have contributed to the surge in electronic device use such as laptops, phones, and tablets leading to the constant e-waste generation.[433] The improvement in consumers' purchasing power and technological advancement has led to faster electronics and electrical equipment obsolescence,

[430] Al-Anzi, Bader S., Abdul Aziz Al-Burait, Ashly Thomas, and Chi Siang Ong. "Assessment and modeling of E-waste generation based on growth rate from different telecom companies in the State of Kuwait." *Environmental Science and Pollution Research* 24, no. 35 (2017): 27160-27174. P.2
[431] Ithraa. Briefings from Oman. Waste management. https://ithraa.om/portals/0/IthraaPDF/Brochures/PDF/ithraa_briefings_waste_engAW.pdf
[432] Henry, Jonathan K., and Angayar K. Pavanasam. "Waste mobiles and computers: A critical evaluation." P.2 https://www.researchgate.net/publication/313397733_Waste_mobiles_and_computers_WMC_A_critical_evaluation
[433] Henry, Jonathan K., and Angayar K. Pavanasam. "Waste mobiles and computers: A critical evaluation." https://www.researchgate.net/publication/313397733_Waste_mobiles_and_computers_WMC_A_critical_evaluation

causing a rapid increase in e-waste. It is estimated that 17kg of e-waste is generated in Oman per person.[434]

Notably, the e-waste produced in 2017 alone was 110810 tons.[435] Most wastes include old desktops, laptops, keyboards, monitors, mobile phones, printers, and hard disks. In 2020, the Global E-waste Monitor reported that Oman generated 69 kt in 2019, translating to 15.8 kg per capita.[436] The generation of e-waste per person was similar to what was generated in Kuwait in the same period in 2019, as illustrated in Figure 7.1 above. However, the total e-waste generated in 2016 in Oman was 29 kt, which translates to 11.3 kg per capita, as illustrated below.

Figure 7.3.: GCC E-waste Generation in 2016

Country	E-waste generated (kt) (2016)	E-waste generated (kg per capita) (2016)	E-waste documented to be collected and recycled (kt)	National e-waste legislation/policy or regulation in place
Bahrain	20	15.5	-	No
Kuwait	67	15.8	-	No
Oman	59	14.9	-	No
Qatar	29	11.3	-	No
Saudi Arabia	508	15.9	-	No
United Arab Emirates	134	13.6	-	No

Source: Baldé et al.: *The Global E-waste Monitor 2017*[437]

[434] Averde launches e-waste collection in Oman. https://www.averda.com/news/averda-launches-e-waste-collection-in-oman

[435] Nasseri, Zainab Al. Oman to host region's largest e-waste processing plant. https://www.omanobserver.om/article/38011/Front%20Stories/oman-to-host-regions-largest-e-waste-processing-plant

[436] Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam. https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/Global-Ewaste-Monitor-2020.aspx

[437] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017). https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

7.1.4 Generation of E-Waste in Qatar

Every year in Qatar, thousands of electronic and electrical equipment such as monitors, fax machines, printers, computers, televisions, copiers, and other electronic devices become obsolete thus abandoned by consumers.[438] The increased advancement in technology and expansion in demand for modern devices have accelerated Qatar's production of e-wastes. Qatar generates over 2.5 million tons of waste yearly. Additionally, the per capita waste generation is estimated at 1.8 kg per day.[439] Notably, Qatar has an annual per capita e-waste generation of 16.3 kg, while the total yearly waste production is 32000 tons. In 2020, the Global E-waste Monitor reported that Qatar generated a total of 36 kt of e-waste in 2019, which translates to 13.6 kg per capita.[440]

7.1.5 Generation of E-Waste in Saudi Arabia

The Kingdom of Saudi Arabia, considered the largest GCC country produces approximately 15 million tons of waste yearly. The country has the largest population in the GCC, as shown in **Figure 7.5.: Population in the GCC countries 2021.** Additionally, the per capita waste generation is about 1.4 kg per person daily. Notably, the per capita e-waste generation is 12.5 kg every year, while the total annual e-waste production is estimated to be 378000 tons.[441] Despite its large population, the Kingdom's per capita e-waste generation was the least among GCC countries in 2014.[442] Figure 7.4. below illustrates the statistics of e-waste generated within the GCC in 2014.

[438] Al Haya. E-waste recycling. http://www.alhayaqatar.com/ewasterecycling
[439] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.4
[440] Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam. https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/Global-Ewaste-Monitor-2020.aspx
[441] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.5
[442] Widmer, Rafael. "Recycling of e-waste in GCC: Challenges and opportunities." https://www.ecomena.org/ewaste-recycling/

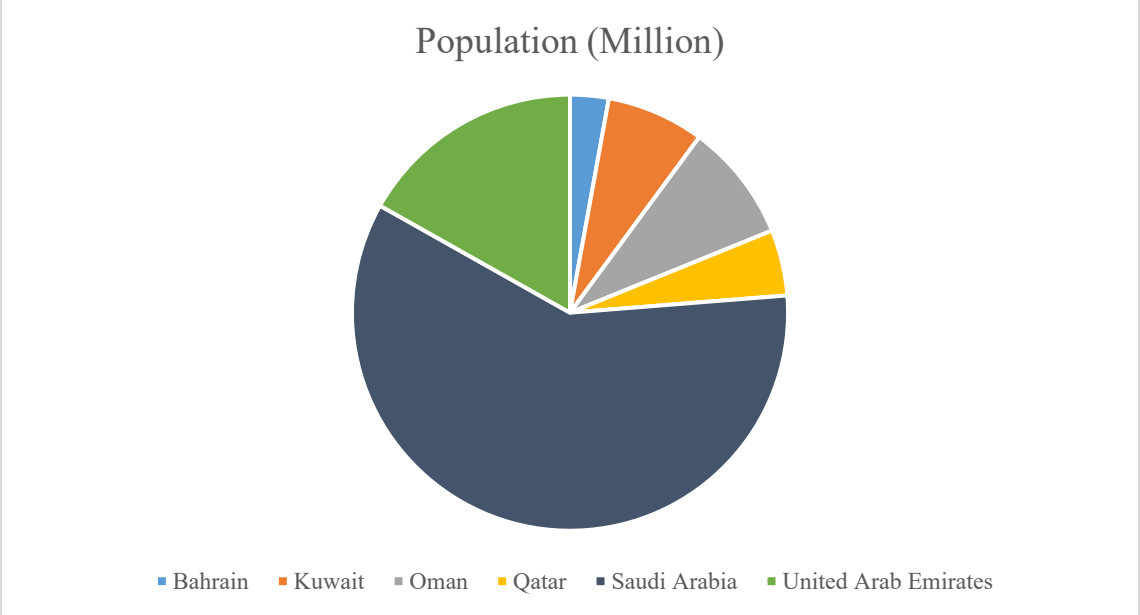
However, the latest statistics show that Saudi Araba has the highest per capita e-waste generation of 17.6.

Figure 7.4.: GCC E-waste Generation by Population in 2014

Country	Population (Million)	Per capita E-waste (kg)	Total (Thousand tons
Bahrain	1.2	12.9	15
Kuwait	4	17.2	69
Oman	3.3	14	46
Qatar	2	16.3	32
Saudi Arabia	30	12.5	378
United Arab Emirates	5.9	17.2	101
Total E-waste in GCC in tons			642

Source: Alghazo & Ouda: *2nd ICIEM 2016*[443]

Figure 7.5.: Population in the GCC countries 2021



In 2015, the Global E-waste Monitor reported that Saudi Arabia generated 379 kt and 12.5 kg per capita, the lowest per capita in the GCC. Subsequently, the Kingdom of Saudi Arabia has

[443] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016.

been topping the per capita e-waste generation. For instance, the 2017 Global E-waste Monitor reported that Saudi Arabia generated 508 kt in 2016, translating to 15.9 kg per capita. In the 2020 report by the Global E-waste Monitor, the same trend was maintained. The report noted that Saudi Arabia generated 595 kt in e-waste in 2019 and 17.6 kg per capita, as shown in **Figure 7.1.: E-waste Production Levels.**

7.1.6 Generation of E-Waste in the United Arab Emirates

As electronics become vital parts of people's daily lives, their use has surged in the UAE. The country has a per capita e-waste generation of 17.2 kg per year, while the annual e-waste production is 101000 tons.[444] As e-waste generation in the GCC countries increases to a staggering 900000, the e-waste production in the UAE will also surge by the end of 2020.[445] Notably, UAE is one of the top generators of e-waste in the GCC, along with Kuwait.[446] As a result, the UAE government has initiated policies to counter the threat of a surging e-waste generation as electrical and electronic equipment increases. According to the Global E-waste Monitor reports already highlighted in the figures above, UAE has steadily increased its e-waste generation levels. In 2014, for instance, UAE generated 101 kt of wastes which translates to 17.2 kg per capita, which was similar to the per capita rate of Kuwait, as is demonstrated by the figure below.

Figure 7.5.: GCC E-waste Generation in 2014

Country	E-waste generated (kt) (2014)	E-waste generated (kg per capita) (2014)	E-waste documented to be collected and recycled (kt)	National e-waste legislation/policy or regulation in place
Bahrain	16	12.9	-	No
Kuwait	69	17.2	-	No

[444] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.5
[445] Averda. “Averda & Uber collect 946 kilos of electronic waste in the UAE.” https://www.averda.com/news/averda-uber-collect-946-kilos-of-electronic-waste-in-the-uae
[446] The Sustainabilist. “An overview of the e-waste problem and recycling drive in Dubai.” https://thesustainabilist.ae/an-overview-of-the-e-waste-problem-and-a-recycling-drive-in-dubai/

Oman	46	14.0	-	No
Qatar	33	16.3	-	No
Saudi Arabia	379	12.5	-	No
United Arab Emirates	101	17.2	-	No

Source: Baldé et al.: *The Global E-waste Monitor 2014*[447]

However, a similar report in 2017 revealed that UAE reduced its per capita e-waste to 13.6 kg, as illustrated by Figure 7.2 above. Kuwait ranked higher than the UAE in the 2017 report in terms of per capita e-waste. Nonetheless, the figure increased in 2019 when the per capita e-waste within UAE stood at 15 kg, as shown in Figure 7.1 above.

7.2 MANAGEMENT OF E-WASTE WITHIN THE GCC

7.2.1 Management of E-Waste within Bahrain

The primary e-waste management method in Bahrain is the use of landfills. However, the country has only one landfill that spreads over 700 acres and is anticipated to reach a total capacity in the coming years. Additionally, Bahrain expects to build a waste-to-energy plant that will enhance the landfill's lifespan. Notably, various recycling initiatives have been established in Bahrain through the involvement of public-private partnerships. For example, private contractors offer five waste recycling locations for collecting plastics, metals, and paper/ cardboard in every governorate of Bahrain.

Bahrain's recycling industry is still small since only a few firms recycle mainly ferrous, non-ferrous, and plastics. Thus, the waste management system in Bahrain is still at the intermediate stage.[448] Notably, despite the high e-waste generation in Bahrain, there is still low awareness of e-waste and the need for sound waste management practices to counter the problem. However,

[447] Baldé, C.P., Wang, F., Kuehr, R., Huisman, J.: The global e-waste monitor – 2014, *Quantities, Flows, and Resources*, (United Nations University, IAS – SCYCLE, Bonn, Germany, 2015). https://i.unu.edu/media/ias.unu.edu-en/news/7916/Global-E-waste-Monitor-2014-small.pdf

[448] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.4

Bahrain emphasizes the benefits of e-waste management due to its limited land resources, making landfilling quite uneconomical and ineffective.[449]

The Environmental Affairs Directorate under the Ministry of Municipalities Affairs and Urban Planning is in charge of the overall waste management in Bahrain. However, the agency focuses on managing the vast collection of municipal waste rather than e-waste. Notably, Bahrain has introduced economic and social development measures aimed at attaining sustainable development.[450] As a result, Gulf City Cleaning Company and Sphinix Services have been appointed to collect e-waste in the Kingdom of Bahrain across all the governorates. Some of the e-waste management initiatives are discussed below.

7.2.1.1 Askar Waste to Energy Project

Askar is the only landfill in Bahrain that covers about 700 acres. The landfill is primarily used to manage municipal wastes, agricultural wastes, and non-hazardous industrial wastes. However, the proximity of the country's main landfill to urban settlements has been a critical concern because of severe environmental and health effects. For instance, the constant accumulation of waste around the landfill is expected to negatively impact soil, air, and groundwater. As a result, the Askar Waste to Energy project was started around the Askar village as part of a public-private partnership to assist in sustainable waste management. The project is a 480-million-dollar incineration facility that will treat more than 390000 tons of domestic waste yearly and produce 25 megawatts of power into the country's national grid.[451] Further, the project

[449] Alameer, Hasan. "Assessment and evaluation of waste electric and electronics disposal system in the middle east." *European Scientific Journal* 10, no. 12 (2014). P.383.
[450] Indrupati, Joel, and Tara Henari. "Consumer Behaviour in E-Waste Disposal-A Case for Setting up an E-Waste Collection and Recycling Facility in Bahrain." P.9
[451] Indrupati, Joel, and Tara Henari. "Consumer Behaviour in E-Waste Disposal-A Case for Setting up an E-Waste Collection and Recycling Facility in Bahrain." P.11

is expected to improve the solid waste management in Minama and offer alternative power generation that will generally enhance Bahrain's economy.

7.2.1.2 Recycling-for-Charity Project

Charity projects initiated by the government and other organizations have also fostered e-waste recycling in Bahrain. As a part of the government's efforts to encourage recycling, the government of Bahrain partnered with Universe Environment BSC to launch a recycling-for-charity project. As a result, 75 spots were established as recycling collection points for all types of waste, including electronic waste. The Recycling-for-Charity Project has been pivotal in augmenting the government's efforts to effectively manage electronic waste and ease the pressure experienced at the Askar landfill.

7.2.1.3 Private Sector E-Waste Recycling Initiatives

I. *Zain National Mobile Phone and E-Waste Recycling Campaign*

Zain Bahrain's national mobile phone and e-waste recycling campaign that began in 2011 has been critical in e-waste recycling in Bahrain. The initiative is part of Zain Bahrain's community social responsibility that primarily focuses on mobile phones. The project provides the public an opportunity to safely dispose of electronic wastes such as old and unusable mobile phones.[452] Further, the non-governmental e-waste management arrangement encourages people to dispose of e-waste responsibly. For example, old and unusable mobile phones are taken to the Zain Experience shops or Polytechnic Bahrain and discarded in separate drop boxes for safe disposal. The electronic wastes are carefully collected, sorted, and effectively disposed of to prevent environmental pollution.[453] Notably, Zain has engaged Enviroserve, a reputable waste

[452] Indrupati, Joel, and Tara Henari. "Consumer Behaviour in E-Waste Disposal-A Case for Setting up an E-Waste Collection and Recycling Facility in Bahrain." P.11
[453] Indrupati, Joel, and Tara Henari. "Consumer Behaviour in E-Waste Disposal-A Case for Setting up an E-Waste Collection and Recycling Facility in Bahrain." P.11

management organization, to handle and dispose of the electronic wastes collected through its initiative.

Further, Zain Bahrain focuses on how individuals can participate in sustainable waste management. The organization runs a competition where people who participate in the safe disposal of their old and unused handsets are rewarded with new phones.[454] As a result, people are encouraged to safely dispose of their mobile phones to avoid causing adverse environmental impacts. Notably, Zain Bahrain employees collected 1.5 tons of e-waste since the second part of the Zain e-waste recycling campaign began in 2019.[455] The wastes generated included old mobile phones, printers, cables, PC and other home and electronic kitchen appliances. Further, Zain Bahrain has partnered with the SCE and Crown industries to bolster its e-waste recycling efforts nationally.

II. *David Hack and Bahrain Computer Repair Center*

The Bahrain e-waste management efforts have been boosted by initiatives of a South African teacher at Rawad Al Khaleed, Saudi Arabia and lives in Bahrain. David Hack has been involved in e-waste recycling in South Africa and initiated the same efforts in Bahrain by partnering with a local investor, Sai Krishna, that launched an initiative to recycle old and unused laptop computers at the Bahrain Computer Repair Center.[456] The company has launched a reverse logistics repair center that primarily deals with recycling e-wastes for reuse to avoid disposing and causing adverse environmental impacts.

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[454] Zain Bahrain. “Press releases.” https://www.bh.zain.com/en/zainbahrain/news/zain-national-mobile-phone-and-e-waste-recycling-campaign-announces-july-and-august-winners
[455] Zain. “E-waste.” https://www.bh.zain.com/en/zainbahrain/ewaste
[456] Indrupati, Joel, and Tara Henari. "Consumer Behaviour in E-Waste Disposal-A Case for Setting up an E-Waste Collection and Recycling Facility in Bahrain." P.12

The Bahrain Computer Repair Center is the collection point where individuals can dispose of unwanted electronic devices or gadgets. The components of the disposed old or unwanted electronics are recovered for reuse or refurbishment.[457] Further, plastics from the dismantled electronic wastes are recycled to make new products, components, and materials, printed circuit boards that are locally processed. The remaining unrecoverable parts are sent to incinerators to ensure sufficient e-waste management.

III. ***Recycle IT, Bahrain***

Recycle IT, Bahrain started as an NGO project to facilitate e-waste recycling to minimize e-waste in the Kingdom of Bahrain. The initiative was launched by the Good Word Society and is sponsored but the United Nations Environmental Program.[458] The project is instrumental in Bahrain's e-waste recycling efforts to protect the environment and human health.

IV. ***BFH Recycling Project***

The Financial Centre Development Company initiated a recycling project for residents of Harbor Towers and Harbor Gate. The firm ran a recycling initiative in the building before engaging Nidukki to manage the recycling project. Notably, Nidukki is a reputable waste management and recycling services provider with more than 35 years of experience in the Kingdom of Bahrain.[459] Several tenants participated in the project to assist in waste recycling to protect the environment.

7.2.2 Management of E-Waste within Kuwait

7.2.2.1 New Air Program by Metal & Recycling Company (MRC)

Kuwait has initiated a comprehensive and robust e-waste management policy. As a result, private initiatives like the New Air undertake the country's primary waste management initiatives. The waste management programs emphasize the collection and recycling of wastes at the corporate

[457] Trade Arabia. "New initiative to tackle e-garbage threat." http://tradearabia.com/news/MISC_215481.html
[458] Indrupati, Joel, and Tara Henari. "Consumer Behaviour in E-Waste Disposal-A Case for Setting up an E-Waste Collection and Recycling Facility in Bahrain." P.13
[459] BFH. "BFH recycling project." http://bfharbour.com/news/bfh-recycling-project

and individual levels. Notably, New Air has been instrumental in training enterprises on the effective ways of managing e-waste.[460] Additionally, the New Air representatives are pivotal in designing robust waste management plans.

7.2.2.2 Enviroserve

Enviroserve undertakes electronic waste recycling, metal waste recycling, and specialized waste recycling. Enviroserve is Kuwait's leading recycling facility supported by the Kuwait National Fund. It strives to fix the e-waste problem and enable industries in the nation to decrease their waste footprint.[461] Enviroserve provides endpoint recycling where its services make life easier by collecting waste, sorting, and processing using the industry best practices.

Further, Kuwait seeks to establish an e-waste sorting and recycling plant to be located from residential areas.[462] The proposed project will prevent the adverse effects of e-waste on the environment and human health while ensuring that valuable minerals like iron, aluminum, gold, copper, and silver are recovered for further use. Therefore, the private sector plays a critical function in Kuwait's management of e-waste.

7.2.3 Management of E-Waste within Oman

Oman has a general waste management strategy that places little emphasis on e-waste management. Landfilling is the predominant waste handling method in Oman. Notably, the Sultanate of Oman sought to establish 65 water waste transfer points, five treatment plants, and 16 engineered landfills by 2015.[463] Most solid waste is usually sent to authorized and unauthorized disposal sites, leading to environmental and health concerns. Further, some landfills are located in

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[460] Alameer, Hasan. "Assessment and evaluation of waste electric and electronics disposal system in the middle east." *European Scientific Journal* 10, no. 12 (2014). P.383.
[461] Enviroserve. https://enviroservekw.com/
[462] The Isosceles Group. "Kuwait proposes recycling of e-waste." https://www.theisogroup.com/blog/kuwait-proposes-recycling-of-e-waste
[463] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016.

residential areas and water catchment areas leading to severe environmental and health impacts. Notably, Oman's solid waste management is characterized by limited collection and disposal facilities and a lack of public awareness about waste in the Sultanate.[464] As a result, solid waste, industrial waste, and electronic waste are disposed of in the large landfills scattered across the Sultanate.

7.2.3.1 Al Amerat Sanitary Landfill

Al Amerat landfill is an engineered landfill in Oman established in 2011. The landfill spreads over 9.6 hectares and has five cells that can handle approximately 10 million meters cube of solid waste. Every cell in the landfill contains 16 shafts for taking leachate water. Notably, the shafts are integrated to assist in moving the contaminated water to the leachate pump. Further, the Al Amerat Sanitary Landfill is part of the government's effort to manage solid waste scientifically and environmental-friendly manner.

Oman focuses its waste management strategy on waste minimization and reduction/recycling.[465] The waste management system is based on global standards and the local procedures that emphasize household waste, sewage, and waste from health, construction, and the oil industry. Additionally, the waste management sector is a critical job source that employs over 6575 persons.

Notably, waste management still relies on landfills/dumpsites primarily controlled by the government.[466] Oman still lacks a robust e-waste management system. However, the increased privatization of waste management is anticipated to encourage investment in e-waste management by private sector players to facilitate robust pre-collection, collection, and innovative e-waste

[464]Zafar, Salman. "Municipal solid waste management in Oman." https://www.bioenergyconsult.com/msw-oman/
[465] Alameer, Hasan. "Assessment and evaluation of waste electric and electronics disposal system in the middle east." *European Scientific Journal* 10, no. 12 (2014). P.384.
[466] Zafar, Salman. "Municipal solid waste management in Oman." https://www.bioenergyconsult.com/msw-oman/

handling processes. Further, Oman prioritizes modern solid waste management practices to explore waste to energy strategies that handle waste sustainably.

Environmental Services Holding Company (OESHC)

The Oman Environmental Service Holding Company SAOC was created in 2007 through the 2009 Royal Decree No. 46/2009.[467] The organization was mandated to undertake solid waste management within the Sultanate. Further, OESHC ensures sustainable waste management practices according to the global standards by establishing the necessary infrastructure, restructuring the municipal waste collection, and enhancing public awareness on waste management. Therefore, OESHC is critical in Oman e-waste management by offering solid and hazardous waste management services, waste recycling and recovery processes, and waste management training services.

7.2.4 Management of E-Waste within Qatar

Qatar is one of the world's first growing economies. However, landfilling remains the primary waste disposal in the country despite the high waste generation of 2.5 million tons per year.[468] Notably, Qatar has three landfills, and a comprehensive waste management strategy is being implemented to attain 38% waste recycling and minimize per capita waste generation. Additionally, various companies are licensed to undertake e-waste recycling in Qatar. For example, one of the notable e-waste recyclers is the Al Haya that serves multiple industries and corporations to enable safe disposal of electronic wastes and protect the environment. Al Haya provides e-waste management for all industries and companies.[469]

[467] Beah. https://www.beah.om/
[468] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.4.
[469] Al Haya. “Services. E-waste recycling.” http://www.alhayaqatar.com/ewasterecycling

7.2.4.1 Qatar Foundation

Qatar Foundation plays a vital role in the country's e-waste management. The organization recycles e-waste and enables the safe disposal of old and used electronics at carefully designed collection points in Education City. Notably, the Foundation's recycle bins are located in Multaqa (Education City Student Center), Penrose House (LAS Building), and Lulu Express at housing lot 4. Additionally, the Foundation collaborates with Al Haya Waste Management Company to promote sustainable e-waste management in Qatar.[470] The common types of e-waste collected by the Foundation include desktop computers, laptops, monitors, printers and copier toners, cartridges, keyboards, TVs, scanners, audio-video equipment, telephones, mobiles, and microwaves.

The Qatar Foundation has successfully run e-waste recycling drives. For example, the organization's campaign in 2019 led to the collection of 4.5 tons of e-waste through the containers located at various points in the Education City and other affiliate organizations.[471] Notably, members of the Qatar Foundation are encouraged to deposit old and unused electronic equipment like computers, laptops, monitors, keyboards, and televisions. The Foundation's initiatives have been instrumental in addressing the rising e-waste challenge and creating awareness of the hazardous effects of e-waste to enhance a culture of sustainability.

7.2.5 Management of E-Waste within Saudi Arabia

Similar to other GCC countries, the primary waste disposal mechanism in Saudi Arabia is landfilling. Waste is collected from the personal and community garbage bins and disposed of in landfills. Notably, the recycling rate in Saudi Arabia ranges from 10-15% because of the

[470] Qatar Foundation. "Qatar Foundation takes action against e-waste." https://www.qf.org.qa/stories/qatar-foundation-takes-action-against-e-waste
[471] Gulf Times. "Qatar e-waste recycling to be annual initiative." https://www.gulf-times.com/story/633601/QF-s-e-waste-recycling-to-be-annual-initiative

involvement of the informal and private sectors in recovering metal, plastic, and paper from municipal waste.[472]

Notably, Saudi Arabia has established new regulations to facilitate an integrated framework for effective waste management. However, robust enforcement of the rules is still limited in the country. Further, awareness of appropriate waste management practices is low within Saudi Arabia, hindering efforts to ensure proper waste management.

The Kingdom of Saudi Arabia has over 40 recycling firms that assist in managing different types of waste. Notably, only a few of the waste recycling organizations focus on electronic wastes. As a result, the management of e-waste has remained a critical concern in Saudi Arabia. In 2012, Saudi Arabia partnered with EXITCOM to create the EXITCOM KSA recycling firm to manage e-waste recycling within the Kingdom.[473] Further, the Chemical Safety and Hazardous Wastes department at the General Authority of Meteorology and Environment has been mandated to undertake e-waste management in the KSA.[474]

The Saudi recycling, reuse, and energy recovery of the wastes remain in the early stages because of limited developments in the waste management sector. For instance, the e-waste recycling process is primarily undertaken by the informal sector with little government contribution leading to the low recycling rate.[475] Further, the recycling processes are manual and labor-intensive because of the slow adoption of technology by the informal sectors. As a result,

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[472] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.4.
[473] Alameer, Hasan. "Assessment and evaluation of waste electric and electronics disposal system in the middle east." *European Scientific Journal* 10, no. 12 (2014). P.384.

[474] Ahmad Filimban, Asma Abdullah, Furat Ahmed Mahmood Al-Faraj, and Akponanabofa Henry Oti. "Towards Sustainable Management of E-Waste in the Kingdom of Saudi Arabia: A Comparative Study of Three International Models." *Journal of Bioscience and Applied Research* 5, no. 3 (2019): 325-339.
[475] Radwan, Neyara, Nadeem A. Khan, and Rania Abdou Gaber Elmanfaloty. "Optimization of solid waste collection using RSM approach, and strategies delivering sustainable development goals (SDG's) in Jeddah, Saudi Arabia." *Scientific reports* 11, no. 1 (2021): 1-12.

the Saudi government has created the Saudi Recycling Company to support the local recycling projects. The SRC aims to increase the recycling rate to 83% from the low 10% by 2030.[476]

Additionally, Saudi Arabia seeks to establish 3GW of waste-to-energy facilities by 2030 to efficiently manage solid waste and add to the country's national power grid. The 3GW waste-to-energy project will also be instrumental in diversifying the country's energy. Further, the Saudi Vision 2030 creates a plan that targets 100% of municipal waste, 60% construction waste, and 85% industrial wastes.[477] The Kingdom seeks to create a circular economy premised on recovering nutrients to the earth and rechanneling recovered recyclables to industries. Some of the critical players in the waste recycling initiatives include the Ministry of Environment, Water and Agriculture, Saudi Investment Recycling Company, the National Recycling Center, and the Ministry of Municipal and Rural Affairs.

7.2.6 Management of E-Waste within the United Arab Emirates

The management of e-waste has become a critical concern in the United Arab Emirates. Notably, the increased per capita income among persons in the UAE has led to the rise in e-waste generation.[478] As a result, the UAE government has created an integrated waste management system that seeks to divert over 75% of municipal waste, including electronic waste from landfills, as part of the country's Vision 2021.[479]

Currently, UAE has the most active involvement in e-waste management in the GCC. The country has developed robust e-waste regulations and legislation to ensure the proper handling of e-waste. Further, there is increased focus on the public-private partnership where municipalities in

[476] SGE. "Saudi Arabia: Looking for waste-management solutions." https://www.s-ge.com/en/article/global-opportunities/20184-c6-saudi-arabia-waste-management
[477] ITA. "Saudi Arabia & environmental technologies." https://www.trade.gov/market-intelligence/saudi-arabia-environmental-technologies
[478] Alghazo, J., and Omar KM Ouda. "Electronic waste management and security in GCC countries: a growing challenge." In *ICIEM international conference, Tunisia*. 2016. P.4.
[479] The Sustainabilist. "An overview of the e-waste problem and a recycling drive in Dubai." https://thesustainabilist.ae/an-overview-of-the-e-waste-problem-and-a-recycling-drive-in-dubai/

the 7 Emirates collaborate with private firms to recycle e-waste effectively. As a result, the local authorities effectively manage waste through safe recycling and proper separation and collection systems.

Notably, one of the largest recycling plants has been established in Dubai Industrial City in collaboration with Enviroserve. The recycling facility can process about 39000 tons of e-waste annually. Additionally, another recycling plant is being built in Sharjah to recover energy from waste and recycle e-waste.[480] The facility is anticipated to divert 300000 tons of solid waste from landfills. Additionally, Abu Dhabi created a strategic plan aimed at diverting 85% of electronic wastes by 2018.[481]

7.2.6.1 Averda recycling waste in Dubai

Averda Dubai has partnered with the Dubai Municipality to offer e-waste collection services in the Emirate of Dubai.[482] The strategy aims to promote integrated and effective sustainable waste management within the Dubai Municipality to safeguard the environment, reduce the generation of unrecyclable waste and foster efficient adoption of waste management technologies. Further, Averda Dubai has offered the Municipality of Dubai technology-efficient e-waste bins following the partnership. The smart e-waste bins are equipped with sensors that enhance the proper management of waste. Additionally, the bins have intelligent systems that offer analysts data on the filling level '2and anticipated collection dates. Notably, all waste collected is sorted in the waste processing plants and taken to recycling facilities.[483] However, e-wastes like

[480] The Sustainabilist. "An overview of the e-waste problem and a recycling drive in Dubai." https://thesustainabilist.ae/an-overview-of-the-e-waste-problem-and-a-recycling-drive-in-dubai/
[481] Veracity World. "E-waste in UAE: Current scenario, issues and strategies." https://www.veracityworld.com/e-waste-management-dubai-uae/
[482] Averda. "Dubai is leading the trend in terms of electronic waste recycling." https://www.averda.com/news/dubai-is-leading-the-trend-in-terms-of-electronic-waste-recycling
[483] Averda. "Dubai is leading the trend in terms of electronic waste recycling." https://www.averda.com/news/dubai-is-leading-the-trend-in-terms-of-electronic-waste-recycling

laptops are collected and taken to the Dubai Municipality for refurbishment and handed to the socially disadvantaged persons in society.

7.2.6.2 Sims Recycling Solutions in Jebel Ali

The Sims Recycling Solutions in Jebel Ali has also been instrumental in e-waste recycling and disposal in the UAE. The company is a global e-waste recycling services provider in Dubai. Notably, Sims Recycling Solutions has expanded its operations in the UAE by acquiring a new facility to enable faster processing of electronic waste materials and reduce lead times for e-waste recycling and IT asset disposition.[484] Additionally, the company offers 100% electronic data destruction and reporting to enable clients to attain sustainability and data security goals.

7.2.6.3 Government Endorsed Enviroserve

Enviroserve is also a critical player in e-waste management in the UAE. The organization is one of the largest electronic waste recyclers across the globe. Further, the organization serves the UAE government, municipalities, commercial and industrial firms by providing e-waste recycling, refrigerant gas recycling, and IT asset disposition and refurbishment. Notably, Enviroserve's advanced technology and facilities surpass the minimum EU standards on e-waste recycling.[485] As a result, the UAE Ministry of Environment endorsed the organization's efficiency in destroying, dismantling, and repurposing electronic waste.

Conclusion

This chapter has discussed the status of e-waste generation, quantities, and flows within the Gulf. Bahrain is one of the largest per capita e-waste generators in the GCC. The nation experiences challenges in e-waste management because of its high population growth and limited landfills. Notably, the country had only one landfill, Askar, located near urban settlements, thus

[484] Sims Lifecycle Services. "Sims Recycling Solutions Dubai moves to new location." https://www.simslifecycle.com/press-releases/sims-recycling-solutions-srs-dubai-moves-to-new-location/
[485] Enviroserve. https://enviroserve.org/

posing high environmental and health risks. Bahrain's e-waste generation per capita as of 2019 was considerably high at 15.9, followed by Oman and Kuwait 15.8 and 15.0, respectively. Notably, Saudi Arabia has the highest e-waste generation per capita at 17.6. The rapid e-waste generation is attributed to the large population of 35340683 as of 2021. The United Arab Emirates has the highest e-waste generation of 162 as of 2019 after Saudi's 595kt. Further, the e-waste per capita generation in UAE is 15, slightly higher than Qatar's 13.6 kg per capita as of 2019.

Landfilling remains the most used e-waste management technique used by the GCC countries. Bahrain operates one landfill that spreads over 700 acres. The GCC countries are also establishing public-private sector e-waste management arrangements to include the private sector in e-waste management. For example, the Askar Waste to Energy project is a part of a public-private partnership to assist in sustainable waste management in Bahrain. Private initiatives like the New Air in Kuwait are instrumental in the GCC countries' primary waste management initiatives. Like other GCC countries, landfilling remains the primary e-waste disposal mechanism in Saudi Arabia.

Additionally, other private sector players are also involved in e-waste collection, treatment, recycling, and disposal in Saudi Arabia. Qatar also relies on landfilling for e-waste disposal. Notably, the Qatar Foundation is also critical in Qatar's e-waste management by locating recycle bins in strategic places to collect old and used electronics for recycling and safe disposal. Oman has established an engineered landfill that handles 10 meters cube of solid waste. The country focuses on waste minimization and recycling and reuse to ensure environmental protection. Notably, the UAE has the most robust e-waste management system in the GCC. The country has comprehensive e-waste regulations and legislation for the adequate handling of e-waste. Like other GCC states, the UAE has established public-private partnership arrangements involving private

companies in e-waste handling within the seven emirates. Therefore, this chapter finds that landfilling is the most used e-waste management method in the GCC countries. Further, public-private partnership is critical in e-waste management through the involvement of private firms and organizations. The next chapter will discuss the findings of all the other chapters, focusing on their applicability to the GCC.

CHAPTER EIGHT

FINDINGS, ANALYSIS, AND DISCUSSIONS OF LEGAL FRAMEWORK WITHIN THE GCC

8.0 Introduction

This chapter summarizes the findings of all the previous chapters, emphasizing their applicability in the GCC. The research objective was to establish whether the GCC has an adequate legal framework to handle the e-waste challenge and realize the economic benefit of e-wastes. Chapter 6 and 7 discussed the environmental laws and the trends on e-waste generation within the GCC member states. Although numerous laws relate to waste generally, few of such laws regulate e-waste directly. As seen in the first part of this chapter, most regulations within the GCC member states only promulgate general principles. Besides, the GCC laws deal more with maritime pollution than hazardous wastes from waste electricals and electronic equipment. Therefore, the first part highlights the findings from the discussion of the GCC laws in Chapter 6. Notably, the second part of this chapter narrates the research results of GCC member states' compliance with the principles of environmental regulations. These principles were highlighted in Chapter 3 of this research and form the basis of most legislations. Finally, this chapter deals with findings on e-waste management trends highlighted in Chapter 7.

8.1 LEGAL FRAMEWORK ON E-WASTE MANAGEMENT

8.1.1 International Treaties on Hazardous Wastes

This research has been concerned mainly with five international treaties and protocols ratified, acceded, or accepted by the GCC member states. These treaties include Basel Convention,

1989;[486] Stockholm Convention, 2001;[487] Minamata Convention, 2013;[488] Rotterdam Convention, 1998;[489] and the Montreal Protocol, 1987.[490] The treaties are discussed in Chapter 5, and their domestication among the GCC member states is highlighted in Chapter 6. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal is one of the most important conventions that regulate transboundary movement and trade of hazardous wastes. The convention is tailored towards ensuring environmentally sound management of hazardous wastes. Proper management of wastes prioritizes environmental and human health concerns.[491] Notably, all the GCC member states are state parties to the Basel Convention.[492] Therefore, the convention offers an e-waste management framework to be implemented by the GCC states in managing e-waste, particularly recycling.

Despite ratifying the Basel Convention through different Decrees already discussed in Chapter 6 of this research, information about the implementation of the Basel Convention within the GCC remains scanty. Notably, Bahrain ratified the convention in 1992, while the convention entered into force in 1993. Despite this, the law that gives effect to the Convention, Legislative Decree No.21 of 1996 in Respect with the Environment, was enacted almost three years later. Even

[486] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (adopted 22 March 1989, entered into force 5 May 1992) 1673 UNTS 126. Available at: http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

[487] Stockholm Convention on Persistent Organic Pollutants (adopted 22 May 2001, entered into force 17 May 2004) 2256 UNTS 119. Available at: http://chm.pops.int/Portals/0/Repository/convention_text/UNEP-POPS-COP-CONVTEXT-FULL.English.PDF

[488] Minamata Convention on Mercury (adopted 9 October 2013, entered into force 18 May 2017) Available at: http://www.mercuryconvention.org/Portals/11/documents/conventionText/Minamata%20Convention%20on%20Mercury_e.pdf

[489] Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (adopted 10 September 1998, entered into force 24 February 2004) Available at: http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx

[490] Montreal Protocol on Substances That Deplete the Ozone Layer (adopted 16 September 1987, entered into force 1 January 1989) Available at: https://treaties.un.org/doc/Treaties/1989/01/19890101%2003-25%20AM/Ch_XXVII_02_ap.pdf

[491] Ogunseitan, O., 2013. The Basel Convention and e-waste: translation of scientific uncertainty to protective policy. *The Lancet Global Health*, 1(6), pp. e313-e314.

[492] http://www.basel.int/?tabid=4499

then, the Decree is not elaborative on how e-waste is to be managed or recycled. For example, the Decree only speaks to licensing and permits needed to export waste outside the Kingdom of Bahrain for treatment, recycling, or reuse.[493] It equally has a general prohibition on engaging in environmentally hazardous activities.

Article 6 of the Decree prohibits any person from using the environment in a way that causes environmental pollution, deterioration, and damage to natural resources. This article is not specific to hazardous chemicals, especially those listed under Article 1 (Annex I) of the Basel Convention. Annex VIII of the Basel Convention lists e-wastes as hazardous based on entry A1180, while non-hazardous e-wastes are classified under entry B1110.[494] However, the Legislative Decree No.21 of 1996 lacks such specificity, casting doubts to its efficiency in implementing the strict provisions of the Basel Convention. Moreover, Article 18 of the Legislative Decree No.21 of 1996 prohibits the storage and disposal of wastes in ways that violate the set systems, standards, and procedures established by the competent environmental authority. The Basel Convention envisages the establishment of a competent authority within a member state, and to this extent, the Decree may be said to be compliant only on general terms.

A similar analysis can be made from Kuwait's domestication of the Basel Convention. The convention entered into force in Kuwait in 1994 after ratifying the convention in 1993.[495] Kuwait has ratified the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution. The convention regulates the pollution of the marine environment

[493] Kingdom of Bahrain, Supreme Council for Environment. Exporting waste abroad. https://www.sce.gov.bh/en/ExportingWasteAbroad?cms=iQRpheuphYtJ6pyXUGiNqn4yFZX70Gnc
[494] Jonathan Kreuger, 'The Basel Convention and the International Trade in Hazardous Wastes' (2001) in Olav Scrhram Stokke and Oystein B Thommessen (eds.) (2001/2002) 43 *Yearbook of International Cooperation on Environment and Development* 45.
[495] http://www.basel.int/?tabid=4499

from oil and other hazardous substances. Beyond this regional convention and its protocols[496], one cannot point to any national law that sets standards or lists the hazardous and non-hazardous chemicals listed in the Basel Convention.

The Sultanate of Oman accepted the Basel Convention in 1995, and the convention entered into force in the same year. The country established the Royal Decree No. 114/2001, focusing on environment conservation and pollution prevention to effect the Basel Convention. The law relates to the maritime environment and prohibits pollution of the sea by ships. It mentions handling hazardous wastes by shipowners who must conform to set guidelines. Qatar is also a state party to the Basel Convention. The Executive By-Law for the Environment Protection Law, Decree-Law No. 30 in 2002, has some aspects that reinforce the provisions of the Basel Convention. Article 22 of the law applies to managing and handling wastes and hazardous materials as established in the Basel Convention.

Like Bahrain, the Executive By-Law for the Environment Protection Law, Decree-Law No. 30 in 2002, establishes a competent authority to issue licenses and permits. Such licensing applies to the treatment and handling of hazardous wastes. Further, Article 23 prohibits any importation of hazardous waste or permission of entry, transit, dumping, and burial in Qatar. Notably, the Decree adopts a zero-tolerance approach to the transportation of hazardous wastes to its territory unless authorized by a responsible authority after the approval of the Supreme Council.[497] Therefore, this law and other by-laws govern the management of e-waste within Qatar.

[496] Protocol on the Control of Marine Transboundary Movements and Disposal of Hazardous Wastes and Other Wastes, 1998. https://www.ecolex.org/details/treaty/protocol-on-the-control-of-marine-transboundary-movements-and-disposal-of-hazardous-wastes-and-other-wastes-tre-001298/?

[497] Executive By-Law for The Environment Protection Law, issued vide the Decree Law No.30 for the year 2002. P.19. Available at: http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-NATLEG-NOTIF-Qatar01-DECREE30.2002.English.pdf

Saudi Arabia is also a party to the Basel Convention on hazardous wastes. The Kingdom has passed some environmental laws that domesticate specific provisions of the Basel Convention. Article 14 prohibits the movement of hazardous, poisonous, or radioactive wastes into the Kingdom's territorial waters and exclusive economic zone. Further, all responsible authorities must adhere to the national regulations, standards, guidelines, and instructions regarding the generation, trade, storage, treatment, recycling, and transportation of hazardous wastes.[498] Like other GCC member states, this law leans more towards maritime than e-waste.

Finally, United Arab Emirates is also a party to the Basel Convention on hazardous wastes. UAE enacted Federal Law No. (24) of 1999 to protect and develop the environment. Article 59 of the law provides that any disposal of hazardous wastes must only be undertaken based on the conditions determined by the Executive Order. The Federal Law No. (24) of 1999 also provides for licensing and permits. The provision of licenses for the transportation of hazardous waste is very core in the Basel Convention. The existence of licensing authority and criteria for licensing is a significant step towards addressing the challenges of hazardous wastes.

The second convention that has been discussed in this research is the Stockholm Convention on Persistent Organic Pollutants. Although the convention does not explicitly deal with e-wastes, it is essential to note that some persistent organic pollutants (POPs) are present in waste electrical and electronic equipment. Like the Basel Convention, the Stockholm Convention has been ratified by all the GCC member states. Bahrain passed Ministerial Order No. 4 of 2006 regarding the management of hazardous chemicals. The Ministerial Order establishes a proper monitoring and management system for handling hazardous chemical wastes as listed in the

[498] General Environmental Regulations and Rules for Implementation. P.32. https://elaw.org/system/files/attachments/publicresource/saudiarabia.General%20Environmental%20Regulations.pdf

Ministerial Order No. 7 of 2002. These Ministerial Orders of 2002 and 2006 give effect to some of the provisions of the Stockholm Convention. It is, however, essential to note that the order deals more with pesticides and agricultural chemicals rather than e-wastes in particular.

Similarly, Kuwait has domesticated some of the provisions of the Stockholm Convention in its Law No. 42 of 2014, the country's Environment Protection Law. Article 42 of the law deals with the control of persistent organic pollutants. The law requires a competent authority to determine the conditions for handling insecticides, fertilizers, and soil-improving materials to prevent environmental pollution.[499] Further, Article 43 of the law prohibits using pesticides, organic chlorine insecticides, and other organic chemical compounds in agriculture, health, and other activities unless the conditions, safeguards, and controls given by an Executive By-Law are fully met. Just like the Ministerial Order discussed under Bahrain, Kuwait's law majorly deals with agricultural products rather than POPs found in e-wastes.

Oman has equally ratified the Stockholm Convention to regulate persistent organic pollutants. For instance, Royal Decree No. 114/2001 generally seeks to protect the environment from contaminants, including POPs. The law sets allowable pollution limits and makes no specific reference to those pollutants in electrical and electronic equipment. Moreover, a similar observation can be made of Qatar, a state party to the Stockholm Convention. Even though Qatar has laws that make references to pollutants generally, there are no specifications for POPs found in waste electrical and electronic equipment. Law No.30 of 2002, the Law of the Environment Protection, prohibits some chemicals and pesticides, especially for agricultural, public health, and other purposes to protect the environment from pollution. Unlike other GCC states already discussed, Qatar has a specific National Implementation Plan (NIP) for Stockholm Convention

[499] Law No. 42 of 2014 Promulgating the Environment Protection Law.p.32. http://extwprlegs1.fao.org/docs/pdf/kuw142030E.pdf

developed by the Supreme Council for the Environment and Natural Reserves (MoE).[500] Nonetheless, the scope of its laws and National Implementation Plan deals more with agricultural products than POPs in e-wastes.

Saudi Arabia also lacks a specific law that implements the provision of the Stockholm Convention other than the General Environmental Regulations and Rules for Implementation. However, the Kingdom deals with POPs through its General Authority of Meteorology and Environment Protection.[501] Similarly, the United Arab Emirates has a national implementation plan to mitigate the risks of persistent organic pollutants and protect the environment at every stage from production, use, and handling. The UAE plans to take measures towards implementing regulatory obligations and reducing organic pollutants.[502] The priority of the GCC states under the Stockholm Convention is agricultural chemicals and their effects on the environment instead of a general approach to all POPs, especially those found in waste electrical and electronic wastes.

The third convention ratified by the GCC member states is the Minamata Convention on mercury. As already noted in Chapter 5, the Minamata Convention applies to e-wastes because some electronics have mercury as one of their components. The laws domesticating this convention within the GCC member states remain scanty save for Royal Decree 58/2020[503] from Oman and Qatar's national plan of eliminating mercury to reduce its risks and damage to human health and the environment.[504] Similar findings can be made for the Rotterdam Convention and

[500] The State of Qatar Ministry of Environment National Implementation Plan (NIP) for Stockholm Convention on Persistent Organic Pollutants (POPs). http://extwprlegs1.fao.org/docs/pdf/qat199284E.pdf
[501] "Saudi Arabia Takes Part, in Basel, Rotterdam, Stockholm Conventions, in Geneva the Official Saudi Press Agency." www.spa.gov.sa/viewfullstory.php?lang=en&newsid=1624366.
[502] FAO. UAE national implementation plan under the Stockholm Convention on Persistent Organic Pollutants (POPs). http://www.fao.org/faolex/results/details/en/c/LEX-FAOC202863/
[503] Royal Decree 58/2020 Approving the accession of the Sultanate of Oman to the Minamata Convention on Mercury. https://mjla.gov.om/eng/legislation/decrees/details.aspx?Id=1197&type=L
[504] National program on the elimination of mercury in the State of Qatar. https://www.un.org/esa/dsd/susdevtopics/sdt_pdfs/meetings/ws1209/presentations/al-sulaiti.pdf

the Montreal Protocol. Although GCC member states have ratified these conventions, there is little indication of the specific laws implementing their provisions under national laws.

8.1.2 GCC Supreme Council Laws and Treaties

The GCC has promulgated laws, regulations, decrees, and unified codes that generally regulate environmental pollution and harm to human health. The GCC member states also have ratified the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution. This convention relates to maritime pollution from oil, toxic chemicals, and wastes. The convention has protocols that deal explicitly with the transboundary movement of hazardous wastes.[505] Other regulations have been in existence since the 1990s and regulate environmental and human health concerns through general principles like the General Regulations of Environment in the GCC States, 1997. The regulations follow the agreement of the Supreme Council on various initiatives during the 6th session in Muscat, Oman, in 1985 to establish a robust system for safeguarding the environment, including the fundamental rules for environmental protection.[506]

As a basic rule in the general principles in the GCC, environment protection considerations should be prioritized to prevent adverse effects from various activities like agricultural, construction, and industrial operations to the environment.[507] The regulations focus on the use of the best available technologies to control pollution and prevent environmental degradation. As discussed in Chapters 2 and 3, using the best available technology is one way of preventing pollution when dealing with inherently hazardous chemicals found in electronics and electrical

[505] Protocol on the Control of Marine Transboundary Movements and Disposal of Hazardous Wastes and Other Wastes, 1998. https://www.ecolex.org/details/treaty/protocol-on-the-control-of-marine-transboundary-movements-and-disposal-of-hazardous-wastes-and-other-wastes-tre-001298/?

[506] General Regulations of Environment in The GCC States 1997. P.1-2. https://www3.nd.edu/~ggoertz/rei/rei880/rei880.147tt1.pdf

[507] General Regulations of Environment in The GCC States 1997. P.1-2. http://www.gcc-sg.org/en-us/CognitiveSources/DigitalLibrary/Lists/DigitalLibrary/Environment/1274260384.pdf

equipment. Further, in Article 6 of the General Principles, a licensing authority is mandated to ensure that new projects and any significant changes to the existing environmental projects apply advanced technology for pollution control and prevention of environmental degradation.

All the technologies used for environmental projects should comply with the ecological feasibility standards to prevent any adverse effects on the environment.[508] The recurrence of competent authority to deal with the licensing of projects on the environment is a progressive move in the GCC laws. Ordinarily, management of e-waste, especially before and during recycling, requires a competent authority to ensure that the economic value of such processes does not override environmental impacts and human health concerns. Equally, the General Principles emphasize traditional technologies, which suggest that the principles support informal recycling. Much about these regulations have already been discussed in Chapter 6 of this research.

Other general laws include the General Environment Protection Law (Muscat, 1995), which the Supreme Council of the GCC adopted in Muscat in 1995.[509] The law forms a regulatory framework similar to that of the General Principles. The third law under consideration is the Common Law for the Environmental Assessment of Projects (Muscat, 1995). This general law is crucial in monitoring the environmental effects of various projects to prevent their negative impacts on the environment, natural resources, and development.[510] The law seeks to protect the environment through proactive impact assessment of projects before and throughout their implementation.

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[508] General Regulations of Environment in The GCC States 1997. P.1-2. http://www.gcc-sg.org/en-us/CognitiveSources/DigitalLibrary/Lists/DigitalLibrary/Environment/1274260384.pdf

[509] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx

[510] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx

The Common Law for Waste Management (Kuwait, 1997) and Common Law for the Management of Hazardous Chemicals (Muscat, 2001) are additional laws regulating the management of wastes and hazardous chemicals in the GCC. Other laws focus on enabling safe and trans-border management of hazardous wastes to facilitate their processing or recycling. The Coordination of Procedures among the Member States for trans-border handling of hazardous waste for processing, recycling, or disposal, 1997 is one of such laws. Member states are expected to use their facilities appropriately to recycle and process hazardous waste to prevent or reduce potential environmental impacts.[511]

The GCC equally has the Common Reference Law for Controlling the Ozone Depleting Materials (Abu Dhabi, 2005). The law seeks to end the utilization of Ozone-depleting materials and replace them with safe alternatives based on the Montreal Protocol and amendments.[512] As was discussed in Chapters 4 and 5, waste electrical and electronic wastes possess some Ozone-depleting substances. However, it remains open to debate how much the GCC states can achieve under this Common Reference Law. Further, the law is augmented by the Unified Law (Regulation) of the Gulf Cooperation Council (GCC) for the Arab States on the Control of Substances that Deplete the Ozone Layer. This Unified Law seeks to eliminate ozone-depleting substances and replace them with safe alternatives based on the Montreal Protocol and amendments just like the Common Reference Law that has already been discussed above. Article 3 of the Unified Law (Regulation) of the GCC on the Control of Substances that Deplete the Ozone

[511] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx

[512] GCC. "Cooperation in the field of human and environment affairs." https://www.gcc-sg.org/en-us/CooperationAndAchievements/Achievements/CooperationinthefieldofHumanandEnvironmentAffairs/Pages/EnvironmentalCooperation.aspx

Layer requires that a competent authority in every member state should provide a comprehensive list of the controlled substances according to the state's obligations about the Montreal Protocol.[513]

8.1.3 National Laws on E-waste Management

The GCC member states have several laws touching on the environment. As highlighted in Chapter 6, Bahrain has some advanced by-laws related to waste management policies in the Middle East and North Africa (MENA) region.[514] These laws are not comprehensive but are the most advanced among the GCC member states. Even though landfilling remains the primary method of managing municipal wastes, including electrical and electronic waste, Bahrain has established legislative decrees and ministerial orders that govern the protection of the environment from hazardous substances in such disposal sites. This research identified two laws in addition to the ones that have been discussed under the international and GCC categories. First, Bahrain passed the Legislative Decree No.21 of 1996 in Bahrain to protect the environment. The Legislative Decree No. (21) of 1996 on the environment offers a comprehensive regulatory framework for managing hazardous wastes. The provisions of the law are designed to protect sources and polluting factors to stop environmental degradation. Notably, Article 14 of the Legislative Decree No. 21 prohibits any trade on hazardous substances and wastes without the approval of the environmental authority.[515]

The second law is Ministerial Order No. 3 of 2006, relating to managing hazardous wastes, which also applies to e-wastes. As already noted in Chapter 6, the law creates an effective monitoring and control system for generating, storing, transporting, and treating hazardous

[513] Unified Law (Regulation) of the Gulf Cooperation Council (GCC) for the Arab States on the Control of Substances that Deplete the Ozone Layer. http://www.fao.org/faolex/results/details/en/c/LEX-FAOC175545/
[514] Alameer, Hasan. "Assessment and evaluation of waste electric and electronics disposal system in the middle east." *European Scientific Journal* 10, no. 12 (2014). P.382.
[515] Bahrain Legislative Decree No. (21) for the year 1996 on the (environment (21/1996)). P.3. https://s3.amazonaws.com/rgi-documents/54824f0a8c2002b0a91d6ea7993f1996b6436d43.pdf

waste.[516] Under this law governing hazardous chemicals, the country has established a multi-disciplinary committee to facilitate ecologically sound waste management through a robust national strategy for executing Agenda 21.[517] Although these laws are not comprehensive enough to provide standards for manufacturing electronics, collection, or treatment, they relate to hazardous wastes.

Kuwait is another GCC country that this research focused on and discussed the environmental laws applicable to e-wastes. The country has a general rule that cuts across all environmental spheres. Notably, the Environmental Protection Law No.42 of 2014 establishes and executes comprehensive national programs to regularly survey and monitor environmental standards and indicators in the environmental sectors.[518] Article 55 of Law No. 42 of 2014 applies to the recycling of e-waste using incinerators. The incinerators are to be used in a manner that does not cause environmental harm. Although the law seems proper at first sight, it should be noted that incineration is not an environmentally sound way of managing wastes. Chapter 2 of this research highlighted incineration as one way precious components of e-wastes are lost when used as a recycling technique. Notably, incineration was common among informal recycling sites, especially in Nigerian dumpsites, and was majorly used to recover copper wires. Since Kuwait has not established a technology-based recycling plant, this law on incineration is justified.

The third country under consideration is Oman which lacks any law that touches on e-wastes or hazardous chemicals other than its international and regional commitments that have already been discussed. Nonetheless, Omen has general rules that cut across different spheres of

[516] Kingdom of Bahrain. "The Supreme Council for Environment. Bahrain National Profile to Assess the National Infrastructure for Chemical Safety." p.60 https://cwm.unitar.org/national-profiles/publications/cw/np/np_pdf/Bahrain_National_Profile_update.pdf
[517] Kingdom of Bahrain. The Supreme Council for Environment. "Bahrain National Profile to Assess the National Infrastructure for Chemical Safety." p.41 https://cwm.unitar.org/national-profiles/publications/cw/np/np_pdf/Bahrain_National_Profile_update.pdf
[518] EPA. "Wasters." https://epa.org.kw/en-us/Waste

the environment. The Basic Law of Oman (RD 101-1996) and the Law of Environment and Prevention of Pollution (RD 114-2001) are some of the laws considered under Chapter 6.[519] These laws provide strict penalties for polluting Oman's environment. Waste generators are thus required to take appropriate measures and adopt advanced technologies that the Ministry and other relevant authorities approve to reduce the generation of wastes.[520] Further, manufacturers are required to utilize clean production techniques to mitigate environmental pollution and conserve natural resources.

Qatar, Saudi Arabia, and the United Arab Emirates have some environmental laws regulating environmental issues, as detailed in Chapter 6. The appropriateness of these laws to e-waste remains undefined, and it can be concluded that these countries lack e-waste laws. For instance, Qatar has Law No.30 of 2002 that promulgated the Law of the Environment Protection. Article 25 prohibits establishing projects to treat hazardous wastes unless licensed by the Competent Administrative Authority and the Council.[521] Therefore, any treatment of e-wastes must be undertaken after formal approval by the responsible authority. Article 25 prohibits any disposal of hazardous wastes without meeting the terms and conditions determined by the Executive Regulation. This law equally regulates the importation, handling, or transportation of hazardous wastes unless permitted. Additionally, appropriate measures must be taken when handling the wastes to mitigate any harm to the environment.[522]

The Kingdom of Saudi Arabia has enacted the Environment Regulation, Royal Decree No M/165 of Dhul Qada 1441 Hejra. The Presidency of Meteorology and Environment under the

[519] Sustainable Oman. "Legislation and regulations." https://sustainableoman.com/omani-laws/
[520] Royal Decree No. 114/2001 Issuing the Law on Conservation of The Environment and Prevention of Pollution. p. 13. http://extwprlegs1.fao.org/docs/pdf/oma98254E.pdf
[521] Law No. 30 of 2002 promulgating the law of the environment protection. https://www.almeezan.qa/LawView.aspx?opt&LawID=4114&language=en
[522] Law No. 30 of 2002 promulgating the law of the environment protection. https://www.almeezan.qa/LawView.aspx?opt&LawID=4114&language=en

Ministry of Defense is responsible for supervising environmental affairs in the Kingdom and issuing licenses. The Saudi Environmental Regulations and its Rules of Implementation focus on improving balanced environmental activities, conserving the environment, and enhancing environmental awareness in society.[523] The Kingdom has also proposed Waste Management Regulation through its Ministry of Environment, Water, and Agriculture. Should the draft regulations come into force, it will be a better e-waste law.

The draft regulation seeks to facilitate integrated waste management, minimizing waste production and managing all operations, including sorting, storing, collecting, transporting, and recycling recyclable wastes. Notably, the draft regulatory policy for waste management covers WEEE, waste batteries, hazardous waste, industrial waste, and municipal solid waste. Thus, the regulation solves the problem of the missing link in the GCC laws when it comes to e-waste. Most rules do not distinguish between municipal wastes and e-wastes. The danger of such generalization is that if not separated, the recyclable e-wastes end in the same landmines as other wastes, yet they are relatively more hazardous.

The United Arab Emirates has various municipal by-laws that apply to hazardous wastes. However, information on the national laws remains scanty. Among the municipalities, Abu Dhabi has comparatively better laws. Nonetheless, UAE has two national laws governing hazardous wastes. The first one is the Federal Law No. 24 of 1999 that offers a robust regulatory framework for environmental protection in the United Arab Emirates. Article 9 of the law provides that all responsible individuals for planning, economic, and construction development shall take the necessary measures to safeguard the environment, control pollution, and rationalize the available

[523] General Environmental Regulations and Rules for Implementation. P.6. https://elaw.org/system/files/attachments/publicresource/saudiarabia.General%20Environmental%20Regulations.pdf

resources when implementing their projects.[524] The second law, the Federal Law No. 12 of 2018, aims to regulate the waste management process and integrate techniques and methods of safe disposal. The law promotes the adoption and use of best practices to safeguard the environment and reduce harm to human health.[525] The legislation also applies to the entire waste management cycle from waste generation, separation, collection, transport, storage, reuse, recycling, treatment, and disposal.

In addition to the two federal laws, Abu Dhabi has enacted two by-laws that govern its waste system. The first law, Law No. 21 of 2005 for waste management, specifies the responsibilities of various parties involved in waste management in Abu Dhabi. For example, a Competent Authority is mandated to enhance waste management in the Emirate through interventions such as reducing wastes, recycling and reusing generated waste, and offering treatment solutions for various types of wastes. Further, a Competent Authority is to establish the priorities and best practices for waste disposal. The authority must also coordinate with all other relevant parties to ensure compliance with the waste management regulations.[526] The second law is Decree No. 42 of 2009 Concerning the Comprehensive Environmental Health and Safety Management System (EHSMS) (Abu Dhabi), which seeks to implement the Environment, Health, and Safety Management System in Abu Dhabi. It offers an integrated mechanism for implementing the laws applicable to the environment, health, and safety, safeguarding human health, and conserving the environment and natural resources.[527]

[524] Federal Law No. 24 of 1999 for the protection and development of the environment. P.11. https://www.dewa.gov.ae/~/media/Files/About%20DEWA/Legislations/English/Federal%20Law%20No24%20of%201999%20on%20Enviroment%20Protection.ashx
[525] Federal Law No. 12 of 2018 on the integrated waste management. p.2
[526] Law No. (21) Of 2005 for waste management in the Emirate of Abu Dhabi. P.2
[527] Decree No. (42) Of 2009 concerning Abu Dhabi EHSMS. P.3

8.1.4 Adequacy of the Legal Framework – Discussion

The Global E-waste Monitor has consistently reported that no GCC country has any e-waste laws. The organization's reports of 2015, 2017, and 2020 have formed part of this study. The study has further ascertained claims in these reports by discussing each state's laws and international commitments. Based on the analysis of Chapter 6 and the discussion above, it is necessary to conclude that the GCC states lack adequate legal frameworks to deal with the e-waste problem. The e-waste problem does not just require legal regimes that prohibit the production, transportation, pollution from hazardous chemicals. Notably, an adequate legal system aids in achieving a circular economy in e-waste. Such an economy seeks to turn e-waste into gold by internalizing the pollution effect of e-waste as an environmental externality.

To turn e-wastes into gold or to realize the economic value of e-wastes, a state must grapple with two competing variables. First, the state must ensure its environment is free of pollution from hazardous chemicals found in e-waste. This paper found that e-wastes are inherently hazardous, as established by classifying chemicals found in e-waste. Further, the Basel Convention discussed under Chapters 5, and 6 lists the substances found in e-waste deemed hazardous. Unlike the Bamako Convention, the Basel Convention does not place a total ban on the transportation of e-wastes across borders of member states.

The second aspect that a state has to grapple with in its legal framework is the economic value of e-wastes. As stated in Chapter 4, e-wastes contain valuable metals that, if recycled, can reduce the costs of production associated with raw materials. Notably, a law sensitive to both variables should consider how e-wastes can be allowed into the state but processed in an environmentally sound manner. Some of the principles that contribute to environmentally sound management were discussed in Chapter 3 and analyzed below.

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8.2 COMPLIANCE WITH PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW

Chapter 3 of this research discussed the principles of environmental law that apply to e-waste management. The principles ensure that e-waste management is done in an environmentally sound manner, as already discussed above. The concept of environmentally sound management of e-waste seeks to limit pollution to the environment and human health when dealing with hazardous chemicals. On the one hand, a law can envisage the preventive principle already discussed in Chapter 3 of this research or follow the precautionary principle. These two principles are essential in realizing the economic value of e-wastes.

The precautionary principle requires states to take regulatory actions that prevent harm to the environment or human health where there is no satisfactory scientific truth of such risks happening. It dictates that states should evade the threats of catastrophic damage to human health and the environment, especially where the possibility of such harm occurring is imminent with no certainty of its effects due to the limited scientific knowledge at the time.[528] However, this is not the case with e-waste management in the modern world since the environmental impacts of e-waste are known. Perhaps the only uncertain scientific knowledge would be the effect of recycling procedures in every state. The precautionary principle suggests the obligation to conduct environmental impact assessment (EIA) as a precautionary measure. To this end, some of the GCC laws can be regarded as compliant, especially those requiring that EIA be conducted.

The main reason for stating that the precautionary principle may not apply as much to the current research is the implication of the preventive principle. Notably, the preventive principle is central to the management of e-waste because some components in electrical and electronic equipment are deemed hazardous. Thus, improper handling of waste electrical and electronic

[528] Atapattu, Sumudu. *Emerging principles of international environmental law*. Brill, 2007. Pp. 203 – 204.

equipment can be damaging to the environment and humans.[529] Depending on the specific legislation under consideration, the duty to prevent includes different requirements.[530] Among other conditions, a state is expected to assess the environmental impact of hazardous activities before authorization.[531] The state should equally develop procedures to license or authorize hazardous activities. The methods may include setting the conditions for operation and the consequences of violations.

Similarly, a state needs to limit emissions and other products or standardize processes. Additionally, a state may employ the best available technology (BAT).[532] Unlike the precautionary principle that largely depends on the uncertainty of scientific evidence, the preventive principle also suggests using the best available technology to help prevent pollution. Most legislations discussed in Chapter 6 referred to this concept of the best available technology. Other GCC laws also encouraged the use of traditional technologies in the management of wastes. However, it is essential to note that the existence of these principles alone does not guarantee a finding that the GCC member states are fully compliant with all the principles of e-waste management. Instead, compliance with the e-waste management principles depends on the existence and enforcement of laws and the management mechanisms present in a state.

[529] Lundgren, Karin, *the global impact of e-waste: addressing the challenge.* Karin Lundgren; International Labour Office, Programme on Safety and Health at Work and the Environment (SafeWork), Sectoral Activities Department (SECTOR). – Geneva: ILO, 2012, p. 18. Available at: k8https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_196105.pdf

[530] Fitzmaurice, Malgosia, David M. Ong, and Panos Merkouris, eds. *Research handbook on international environmental law*. Edward Elgar Publishing, 2010: 183.

[531] Sands, Philippe, and Jacqueline Peel. *Principles of international environmental law*. Cambridge University Press, 2012: 246- 249.

[532] Kiss, Alexandre, and Dinah Shelton. *Guide to international environmental law*. Brill, 2007.

8.3 TRENDS IN E-WASTE GENERATION AND THEIR DETERMINANTS

8.3.1 National Data on E-waste Production & Flow

E-waste is measured by the data provided by municipalities the national authorities. Notably, e-waste can also be calculated at the household level. To ascertain the quantity of e-waste generated in a specific region, one will consider two parallel pathways as discussed in Chapter 4 of this research. The first pathway is to consider the consumer preferences and the population within the specific area. This pathway is discussed below under section 8.3.2. The second pathway is by considering the national data on e-waste generated within the period under investigation. This second pathway, just like the first one, starts at the household level. Each household generates wastes which include waste electronic and electrical equipment (WEEE). The data on e-waste may be recorded directly from each home and translated to the generation of wastes per household.

Alternatively, the data on e-waste generated in a specific region may be collected from the municipal waste bins or dumping sites. This method may lack information on e-wastes per household. However, the per capita data is worked out from the total weight of e-waste at the collection bins divided by the total population. This estimation of wastes generated per municipality is recorded in terms of kilo-tons (kt). The data may also reflect the total e-waste that was collected and recycled in a municipality. The municipal data is reported to the national data center and later tallied alongside other municipalities. The information is then transmitted to the international database and regional database for analysis purposes.

The findings of Chapter 7 showed the national data per each GCC member state. There were no data on how each municipality generated in 2014, 2016, and 2019 as recorded in the Global E-waste Monitor. The reports also established that there were no national e-waste data from most of the GCC member states. The absence of national data was compounded by the lack of e-waste legislation within all the GCC member states. Chapter 6 of this research found that the laws

in each GCC state were not specific to e-wastes. Notably, GCC states stand more chances of generating municipal and national data. Chapter 7 of this research highlighted that most GCC states had established competent authorities for licensing and permitting waste management. Further, many governmental and non-governmental initiatives have specialized in e-waste management and recycling. The national data about e-wastes can therefore be directly collected from these initiatives.

Regarding the national data reported to the Global E-waste Monitor 2014 through 2019, GCC member states generated a substantial quantity of e-waste. Saudi Arabia generated the highest volume of e-waste except in 2014 when the total waste recorded was a little lower. In 2015, the Global E-waste Monitor reported that Saudi Arabia generated 379 kt and 12.5 kg per capita, the lowest per capita in the GCC. Subsequently, the Kingdom of Saudi Arabia has been topping the per capita e-waste generation. For instance, the 2017 Global E-waste Monitor reported that Saudi Arabia generated 508 kt in 2016, translating to 15.9 kg per capita. In a 2020 report by the Global E-waste Monitor, the same trend was maintained. The report noted that Saudi Arabia generated 595 kt in e-waste in 2019 and 17.6 kg per capita.[533] Thus, this research found that the data on e-waste regarding Saudi Arabia was directly proportionate to its population. The population as a distinct factor is discussed in 8.3.2. section below.

8.3.2 Population and Consumer Preferences

Part one of this section on national data on e-wastes noted two methods to get the data on e-wastes. The first method is related to consumer preferences and the population within the specific area. Generally, the factor determining the economic value of e-wastes at recycling is the

[533] Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam. https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/Global-Ewaste-Monitor-2020.aspx

consumption rate and trends. There are two ways in which this research dealt with the phenomenon of consumption of electronics. The first consideration was the population that determines the market girth for electronics and electrical products. The second consideration was on consumer preferences. This research found that as of 2014, the Kingdom of Saudi Arabia led the GCC member states at 30 million people. There was little data on the adult population of GCC member states that dealt with a specific type of electronics. However, Chapter 4 discussed this correlation in countries with national data on the internet and mobile signals. This analysis was lacking in Chapter 7 concerning the trends in the GCC due to limited data on the mobile phone signals, procurement of electronic and electrical equipment, and household electronics.

Conclusion

This chapter summarized the findings of Chapter 6 on GCC laws. The environmental laws of GCC member states were designed to outline general principles of environmental regulations. The principles cover environmental impact assessments, waste collection, management, licensing, and permits. They also establish competent authorities that deal with the regulation of environmental activities. Further, GCC has a multi-tier legal framework that combines international conventions, regional treaties, national and municipal laws. Notably, the GCC states are members of several international conventions, including the Basel Convention, 1989;[534]

[534] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (adopted 22 March 1989, entered into force 5 May 1992) 1673 UNTS 126. Available at: http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

Stockholm Convention, 2001;[535] Minamata Convention, 2013;[536] Rotterdam Convention, 1998;[537] and the Montreal Protocol, 1987.[538] These conventions set out comprehensive ways in which a state can deal with hazardous chemicals and wastes. However, the decrees that domesticate these conventions have scanty details about specific regulations of each convention.

Similarly, very few states have national implementation plans. According to this research, the United Arab Emirates has a federal implementation plan to mitigate the risks of persistent organic pollutants and protect the environment at every stage from production, use, and handling. The plan is not specific to e-wastes and leans more on agricultural products. Notably, the regional laws only emphasize maritime pollution. For example, the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution regulates the pollution of the marine environment by oil and other hazardous substances. Beyond this regional convention and its protocols[539], one cannot point to any national law that sets standards or lists the hazardous and non-hazardous chemicals listed in the Basel Convention. Therefore, this chapter finds that the GCC lacks an adequate legal framework to ensure the maximum economic value of e-wastes while minimizing pollution. The next chapter looks at the findings based on Chapter 7 that discusses the trends in e-waste recycling within the GCC. The chapter will analyze and discuss the findings on

[535] Stockholm Convention on Persistent Organic Pollutants (adopted 22 May 2001, entered into force 17 May 2004) 2256 UNTS 119. Available at: http://chm.pops.int/Portals/0/Repository/convention_text/UNEP-POPS-COP-CONVTEXT-FULL.English.PDF

[536] Minamata Convention on Mercury (adopted 9 October 2013, entered into force 18 May 2017) Available at: http://www.mercuryconvention.org/Portals/11/documents/conventionText/Minamata%20Convention%20on%20Mercury_e.pdf

[537] Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (adopted 10 September 1998, entered into force 24 February 2004) Available at: http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx

[538] Montreal Protocol on Substances That Deplete the Ozone Layer (adopted 16 September 1987, entered into force 1 January 1989) Available at: https://treaties.un.org/doc/Treaties/1989/01/19890101%2003-25%20AM/Ch_XXVII_02_ap.pdf

[539] Protocol on the Control of Marine Transboundary Movements and Disposal of Hazardous Wastes and Other Wastes, 1998. https://www.ecolex.org/details/treaty/protocol-on-the-control-of-marine-transboundary-movements-and-disposal-of-hazardous-wastes-and-other-wastes-tre-001298/?

e-waste handling and the role of the government and the private sector in creating a circular economy based on e-wastes.

CHAPTER NINE

FINDINGS, ANALYSIS, AND DISCUSSIONS OF TRENDS IN E-WASTE MANAGEMENT WITHIN THE GCC

9.0 Introduction

This study was conducted to determine the possibility of an e-waste circular economy within the GCC member states. The study sought to identify global best practices in e-waste recycling and compare them with the practices within the GCC member states. The e-waste management practices included the legal framework on e-wastes, environmental law principles including environmentally sound management of e-waste, and the best available technology in e-waste recycling. Equally, this study sought to assess the adequacy of the environmental laws, e-waste management practices, and current technology on recycling within the GCC. Therefore, Chapter 9 documents the findings of the study on the possibility of an e-waste circular economy. It highlights the results on the global practices and compares them with the findings within the GCC member states.

Further, this chapter discusses the findings in three broad categories. First, it discusses findings on environmentally sound management of e-waste. Under this section, there are findings relating to the global e-waste management techniques, international standards, and management techniques within the GCC. The second section of this chapter deals with the results relating to the best available technology. This section mainly records the findings on e-waste treatment technologies. Lastly, the third part discusses findings on public-private partnerships within the GCC.

9.1 ENVIRONMENTALLY SOUND MANAGEMENT OF E-WASTE

9.1.1 Global E-Waste Management Techniques

Global e-waste management is technologically oriented, although there are instances of informal management techniques. Waste management starts with the manufacturing of the products. Depending on the product design, electronics can either have a longer or shorter lifespan. A shorter lifespan would imply a high turnover rate for e-wastes, while a longer lifespan would mean a gradual turnover of e-wastes. Municipal waste systems thus tend to be overwhelmed where electronics have a shorter lifespan. Secondly, products with more toxic materials in their designs are difficult to manage compared to those designed in an environmentally friendly way. Notably, the international standards adopted by the European Union have eradicated most toxic materials in electronics. For instance, the electronic product design adopted by the European Union makes the management of end-life products much easier.

This research studied product design standards under chapter 3 and the recycling technology under chapter 2. Chapter 4 of this research explored the collection methods of waste electrical and electronic equipment. The findings of the study are that the municipal authorities did waste management in most countries. In some instances, the municipal authorities were assisted by the manufactures through a product take-back system. This take-back system is what is formally called the extended producer responsibility (EPR). Usually, the 'Official Take-Back System' is the first scenario of e-waste collection. It can be done by select organizations specializing in the collection of e-waste. Equally, producers can collect e-wastes through the Extended Producer Responsibility (EPR) arrangement. The government may also engage in the official take-back of obsolete electronic equipment. The official collection often happens in three main points. The first point is via the retailers who collect the used electricals and electronic equipment. Local

governments may also designate municipal collection points where electronic wastes may be discarded. Thirdly, there may be selected pick-up services that may go around the city collecting e-wastes.

The second scenario is the collection under the Mixed Residual Waste. This system is where the owners of the products dispose of their obsolete electronics alongside other household wastes into the standard dustbins. Most e-wastes disposed of this way either end up in landfills or municipal solid waste incinerators with a low chance of separation before their final destination. The last scenario is the collection outside the official take-back system and management of e-waste. Such a scenario differs in developed and developing countries. In most developed countries, there are formal waste management practices for municipal waste recycling. Under the third scenario, individual waste dealers or companies collect e-waste then trade them using different channels. The traded e-wastes may end up in metal recycling, plastic recycling, or specialized e-waste recycling.[540] Others may also be exported to other countries for processing or other uses. There are also chances of informal collection in developed countries.

9.1.1.1 Findings and Analysis

Based on these collection methods, it was evident that the preferred scenario for proper e-waste management was the 'Official Take-Back System.' Only through the 'Official Take-Back System' that the final destination for the e-waste collected is a state-of-the-art treatment facility, which recovers the valuable materials in an environmentally sound way. It was also apparent that the 'Official Take-Back System' should be sanctioned through laws explicitly providing for them.

[540] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017) p. 24. https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

Proper e-waste laws play a significant role in e-waste collection, data collection, and management, including recycling. Such data collection may be necessitated by legislation that enables monitoring with recycling and collection targets. At the international level, data on the amount of domestic e-waste collected and recycled are gathered from countries to assess the progress on e-waste management.[541]

Secondly, Mixed Residual Waste is not the best technique. Most of the wastes collected through this second scenario end up in landfills or municipal solid waste incinerators with a low chance of separation before its final destination. Landfilling is very prevalent with no e-waste laws that provide for the 'Official Take-Back System.' Both landfilling and incineration cause environmental pollution and pose health risks to human health. Besides, small equipment, small IT equipment, and lamps are often disposed of under this second scenario in both developed and developing countries.[542] However, the technique of e-waste collection only deals with small equipment. The last case on collecting e-waste traded outside the 'Official Take-Back System' was not studied in detail in this research due to scanty information. These findings at the international levels will be contrasted with those within the GCC in part 9.1.3. below.

The main objective of the research was to investigate the possibility of an e-waste circular economy within the GCC. Thus, this research studied various variables that impact on e-waste economy. The first variable was the legal and regulatory framework. The second one was on consumer trends and e-waste quantities. Lastly, this research focused on the collection, processing, and recycling of e-waste. Notably, the finding under this section is that a circular economy is achievable under two instances. First, there must be a government-sanctioned mechanism for

[541] Baldé et al.: *The Global E-waste Monitor 2017*.
[542] Ibid.

collecting e-waste. This formal e-waste collection mechanism is recognized and practiced internationally through the 'Official Take-Back System.' The 'Official Take-Back System' is sanctioned by law, whether national or municipal. This formal system of the waste collection makes it easier to turn e-waste into an economically viable commodity. For instance, proper collection of wastes directly impacts the amount of WEEE that is recycled. Further, waste directed to recycling reduces environmental pollution and risks to human health, which are central to the e-waste circular economy.

However, the Mixed Residual Waste scenario does not support e-waste circular economy for several reasons. First, this research found that the Mixed Residual Waste scenario is primarily unregulated. Secondly, e-waste collected through the Mixed Residual Waste scenario ended up in landfills and municipal incinerators. However, landfilling and incineration pose a threat to both the environment and human health. Thus, the hazardous nature of e-waste collected through the Mixed Residual Waste will outweigh any benefits from recycling some components, especially copper wires extracted through incineration. Therefore, the best available technique to adopt in an e-waste circular economy model is the 'Official Take-Back System' supported by e-waste legislation.

9.1.2 International Standards and GCC's Compliance

The second consideration under the e-waste circular economy is the standardization of e-waste recycling. International standards are essential in both product design and e-waste management. The standardization looks at eco-friendly manufacturing that remains environmentally sound throughout product lifespan to the end-use point. Notably, standards are critical in strengthening environmental regulation by ensuring that electronic equipment meets

environmental safety requirements.[543] Further, standards promote safety and environmental protection. The standardization process establishes basic rules for the safe and environmentally-friendly management of e-waste and ensures that companies comply with the environmental safety rules. One of the standards studied in Chapter 3 is the European Electrotechnical Committee for Standardisation (CENELEC). The CENELEC is responsible for standardization in the electronic engineering field regarding electronic waste management. The European standards are established to encourage technological development, ensure interoperability, guarantee the safety and health of consumers, and promote environmental health protection.

Secondly, the Waste Electrical and Electronic Equipment Label of Excellence (WEEELABEX) is another standardization regime. The WEEELABEX project developed new standards for managing waste electrical and electronic equipment such as computers, TV sets, fridges, and cell phones. Notably, WEEELABEX is significant in e-waste management because it develops new solutions to raise awareness on the need to ensure appropriate WEEE collection, testing reuse possibilities, optimizing treatment and recycling, creating quality standards and evaluation, offering training to professionals developing information systems and exchange.[544] Thus, the WEEELABEX is instrumental in e-waste management by defining operators' technical and management requirements to meet the e-waste treatment standards.

The third international standard for e-waste management is the Responsible Recycling (R2) Certification, a leading electronics repair, and recycling standard. The R2 standard is primarily used in the United States. It offers a standard set of processes, safety measures, and documentation

[543] CENELEC. *CEN-CENELEC reply to the European Commission consultation on the Competitiveness and Innovation Framework Programme 2007-2013*. n.d. 4-5. https://ec.europa.eu/cip/files/docs/consultation-european-committee-for-electrotechnical-standardization_en.pdf.
[544] European Union. "LIFE & Electrical and electronic waste management (WEEE)." 2-4.

requirements for businesses that repair and recycle used electronics. As such, the US Environmental Protection Agency encourages all electronics recyclers to be certified after demonstrating to accredited independent auditors that they satisfy the set standards for safe recycling and management of electronic wastes. The main concern for standardization, just like e-waste legislation, is to regulate e-waste recycling procedures. Like the two standards of CENELEC and WEEELABEX, R2 seeks to standardize e-waste management processes, including recycling.

As already discussed in Chapter 3 of this research, R2: Requirements provide that an e-waste recycler must possess and use an Environmental Health and Safety Management System (EHMS) for planning and monitoring its environmental, health, and safety practices. Notably, R2:2013 requires that all recyclers not direct e-waste material to incineration, energy recovery, or land disposal unless there are no recycling and reuse options. Thus, recyclers must take due considerations before directing electronic materials to energy recovery or incineration to ensure that all the viable options for recycling and reuse are exploited.

Another standard studied in this research is the Electronic Product Environmental Assessment Tool (EPEAT), an international ecolabel that applies to the IT sector. The EPEAT assists buyers, manufacturers, resellers, and others to buy and sell environmentally friendly electronic products.[545] The EPEAT was established using a grant from the US Environmental Protection Agency and is managed by the Global Electronics Council. [546] Electronic products registered by the EPEAT must meet the environmental performance criteria that involve material selection, supply chain greenhouse gas (GHG) emissions reduction, product design for circularity,

[545] Africa Clean Energy Technical Assistance Facility. "E-Waste Policy Handbook Africa Clean Energy Technical Assistance Facility. 2019. E-Waste Policy Handbook." Last modified 2019. 22-23. https://www.ace-taf.org/wp-content/uploads/2019/11/ACE-E-Waste-Quick-Win-Report20191029-SCREEN.pdf.
[546] EPA. "Electronic Product Environmental Assessment Tool (EPEAT)." US EPA. Last modified March 18, 2021. https://www.epa.gov/greenerproducts/electronic-product-environmental-assessment-tool-epeat.

product longevity, energy conservation, and end-of-life management. Some of the products covered by EPEAT include computers and displays, imaging equipment, photovoltaic modules and inverters, TVs, servers, and mobile phones.

Lastly, the Swiss SENS/SWICO Technical Standard was studied under this research. The SENS/SWICO is the official technical standard of Switzerland which came into force on 8th December 2009. The standard applies to the recycling of WEEE in Switzerland. [547] It complements the existing regulatory framework through its general technical and detailed directives for recycling electronic equipment. The SENS/SWICO recycling standards apply to electrical appliances in computing, consumer electronics, office equipment, telecommunications, and medical instruments. Some electrical products regulated by the standards are copiers, printers, TVs, MP3 and MP4 players, mobile phones, and cameras. Further, SENS/SWICO recycling standards focus on removing electrical and electronic components with harmful substances and ensuring their appropriate recycling. [548] As a result, the standards contribute to the safe recycling of e-waste as toxic materials are removed.

9.1.2.1 Findings and Analysis

Proper e-waste recycling depends on standardization that will ensure that harm is minimized while maximizing profits. Standardization seeks to secure several aspects of the e-waste circular economy. From the findings of this study, it was evident that standardization ensures that electronics meet recyclable standards where a product design is done in a manner that utilizes only

[547] SRI. "Technical and environmental standards for the treatment of WEEE Comparison of WEEE-Standards from Switzerland, Europe and the US." Last modified 2015. 4-5. https://sustainable-recycling.org/wpcontent/uploads/2015/07/SRI_ComparisonStandards_2015en.pdf.

[548] *Report of the Technical Inspectorate SENS, SWICO Recycling, SLRS*. 2011. 5-6. http://www.rezagos.com/downloads/Informe-RAEE-SUIZA.pdf.

those materials that are environmentally friendly. Such products are easier to recycle since they do not involve elaborate detoxification treatment. Equally, such products are less hazardous to the environment and human health when dumped in landfills or mishandled. The second aspect of standardization regards the processing of different wastes. Different standards offer prescriptions depending on the scope of the enabling legislation. However, an e-waste circular economy relies on proper selection and separation of wastes before recycling. This aspect of collection and separation has already been highlighted under the 'Official Take back System.' As a result, the WEEELABEX defines operators' technical and management requirements to meet the e-waste treatment standards. The technical guidelines are similar across the different criteria and labels.

This study's findings were that standards are essential in e-waste recycling and should be embraced by any country that wishes to turn its e-waste problem into gold. However, the standards alone are not sufficient. There is a need for the standards to be backed up by a transparent e-waste legal regime. For instance, all the standards studied were created by specific laws on producing electricals, disposal, and recycling of the WEEE. Notably, the existence of standards in the recycling of e-waste is an indicator of the possibility of an e-waste circular economy. The standards comprise some of the best practices in internalizing the hazardous nature of waste electrical and electronic equipment. One of the objectives of this research was to study the best practices in e-waste recycling. Standardization, therefore, emerges as one of the best global practices in e-waste recycling. As discussed in Chapter 3 of this study, the Responsible Recycling (R2) Certification is one of the leading electronics repair and recycling standards.

The R2 promotes safe recycling and management of electronic wastes by setting several standards to be met by environmental agencies. Some of the best practices under this regime include creating a system that aids in planning and monitoring recycling activities. Under the R2:

Requirements, an e-waste recycler must possess and use an Environmental Health and Safety Management System (EHMS) for planning and monitoring its environmental, health, and safety practices, including all the activities undertaken to comply with every requirement of the R2:2013 Standard.

Notably, establishing a system accessible to all agencies limits the hazardous effects of e-wastes both to the environment and human health. Further, the location of a recycling plant is just as important as the health of the workers and the community surrounding the recycling facility. Therefore, a standardization system ensures that all facilities are located away from densely populated cities as a precautionary and preventive measure against adverse effects on human health. Such a monitoring system is accompanied by documenting all the scope of operations encompassed in the R2:2013 and EHSMS certifications to enable assessment and monitoring of the recyclers' conformity to the safe recycling procedures and standards. The R2:2013 also requires every electronics recycler to develop and adhere to a policy for managing the used and end-of-life electronic equipment based on the reuse and recovery hierarchy of the responsible management strategies.

Further, R2: 2013 provides specific directions on the recovery of materials and pre-recycling treatments. According to the R2 requirements, all electronic recyclers are expected to undertake practical measures towards separating materials in electronic equipment and components through manual dismantling or, in some cases where appropriate, mechanical processing. This provision on pre-processing treatment is vital in achieving maximum recyclable materials. The pre-processing treatment is discussed as a separate variable under this study. Chapter 2 studied the best practices and the best available technology on e-waste treatment and material recovery. The findings of Chapter 2 are discussed below in section 9.2.

Notably, it is essential to appreciate the relationship between recycling standards and the best available technology. Both are intended to achieve a circular economy in e-waste management. The existence of provisions on material recovery in recycling standards confirms that a regulatory framework including standards informs best practices in e-waste recycling. Additionally, R2:2013 requires that all recyclers do not direct e-waste material to incineration, energy recovery, or land disposal unless there are no recycling and reuse options. Thus, recyclers must take due considerations before directing electronic materials to energy recovery or incineration to ensure that all the viable options for recycling and reuse are exploited.

Further, the standardization captured by the R2 requirements highlights the danger of incineration and the preference of global practices towards recycling and reuse other than dumping. Although the findings on environmentally sound management of e-waste are cross-cutting, it is essential to note the role of standards in e-waste management. R2 measures discourage recycling facilities from incineration and landfilling. Further, the e-waste circular model works only with high-tech recycling technology instead of indiscriminate dumping and incineration. Thus, the finding of this research based on the R2 standard is that best practices on turning e-waste into economically viable business favors recycling of e-waste to incineration or dumping in landfills.

The best practices on e-waste recycling equally distinguish different types of materials from the Focus materials. Section 3 (2) of the R2 Practices defines focus materials as items containing PCBs, mercury, CRTs and CRT glass, batteries, and whole and shredded circuit boards. The R2: 2013 Requirements is critical in e-waste management by specifying the procedures for removing Focus Materials. The materials must be removed using safe and effective mechanical processing or manual dismantling before shredding or materials recovery of equipment or

components.[549] However, e-waste materials with mercury are to be excluded from the procedure to prevent the release of toxic wastes to the environment and avoid potential harm to on-site workers. E-wastes with mercury are too small to be removed safely at reasonable costs. Further, workers must be protected from the adverse health risks resulting from mercury handling. Therefore, appropriate measures must be taken when recycling e-wastes containing mercury to avoid harming people and undermining environmental protection.

The standards on Focus materials depict a best practice model that seeks to enforce the international conventions to limit pollutions from the hazardous chemicals present in e-wastes. Moreover, the standards reinforce the environmental principle of environmentally sound management of e-waste. Among the objectives of this study was to identify best practices on environmentally sound management of e-waste. Thus, this research identified disposal in landfills and incineration as environmentally unsound management practices. The study also found that recycling e-waste using the best available technology is one of the most environmentally sound management of e-waste. Recycling of e-waste should also be carried out in a standardized manner to ensure the maximum recovery of materials and minimization of pollution. Recyclers must adhere to specific standards that require them to treat Focus materials separately due to their hazardous nature, thus minimizing pollution. Therefore, the findings on international best practices are compared with the management techniques adopted within the GCC member states below.

9.1.3 Management Techniques within the GCC

Chapter seven of this research studied the e-waste management techniques within the GCC member states. This study established that landfills were the most prevalent technique within all

[549] SERI. "The Responsible Recycling ("R2") Standard for Electronics Recyclers." 8.

the GCC member states. The study also found no recycling standards adopted by the GCC or specific directives on e-waste recycling. Thirdly, the study found that no formal recyclers were dealing with e-wastes. The information on the recycling of e-waste within the GCC remained scanty due to minimal published research on the subject of e-waste. GCC member states also practice the Mixed Residual Waste scenario of collecting e-wastes, explaining the lack of official data on e-wastes within the GCC member states. Most wastes collected through the Mixed Residual Waste scenario end up in municipal waste bins and are either indiscriminately incinerated or dumped in the landfills. Additionally, there were no official data on any use of the 'Official Take-Back System,' yielding data on the total e-wastes that are formally recycled. Besides, this research found no clear guidelines for recycling focus materials, including items containing PCBs, mercury, CRTs and CRT glass, batteries, and whole and shredded circuit boards.

9.1.3.1 Analysis on GCC E-waste Management Techniques

One of the study's objectives was to establish whether the GCC's e-waste management practices are adequate for turning e-wastes into economically viable materials. With the findings on lack of official take-back systems, lack of data, lack of standardization, and non-recognition of focus materials, the GCC practices become inadequate. The practices mostly favor the dumping of e-waste in landfills. Notably, the disposal of wastes is unsustainable based on the limited space in most landfills. Turning e-waste into gold through a circular economy requires that a maximum number of e-wastes be recycled.

Further, recycling needs to be standardized to maximize material recovery. Standardization also helps in restoring sanity in locating recycling facilities. Moreover, recycling e-waste must be appropriately done by considering focus materials. Without proper handling of the focus materials, handling of e-wastes will cause serious health problems and cause environmental harm. The GCC

states lack any proper guidelines for separating and processing focus materials. Thus, recycling e-wastes containing the focus materials are dangerous since they are highly poisonous to the environment and humans.

9.2 USE OF BEST AVAILABLE TECHNOLOGY

9.2.1 Treatment of E-wastes

There were no formal e-waste treatment procedures highlighted in the GCC laws that were studied in Chapter 6 of this paper. This research found that e-wastes were not separated for pre-processing treatment or any other treatment. The GCC municipal waste management techniques were majorly incineration and landfilling. There must be proper recycling techniques and standards to achieve a circular economy. As already discussed above, the standards may provide for the treatment of focus materials. Chapter 2 studied the recycling process and the applicable technology in each process. The study found that hazardous substances contained in e-wastes are removed at the pre-processing stage. This early separation helps protect workers from exposure to hazardous substances and protects the environment.[550] Capacitors, printed circuit boards (PCB), and batteries are separated, pre-processed, and channeled to different facilities to recover copper, nickel, and cobalt. Plastics are equally separated from metals and processed separately. Pre-processing often involves de-gassing chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC) for refrigerants and cooling appliances.[551]

[550] Salhofer, S., Tesar, M., 2011. Assessment of removal of components containing hazardous substances from small WEEE in Austria. Journal of Hazardous Materials 186, 1481–1488. Available at: https://www.academia.edu/28067786/Assessment_of_removal_of_components_containing_hazardous_substances_from_small_WEEE_in_Austria

[551] Scottish Environmental Protection Agency. *Guidance on the Recovery and Disposal of Controlled Substances Contained in Refrigerators and Freezers*. Bristol, 2002. Available at: https://www.sepa.org.uk/media/155012/guidance_-recovery_storage_controlled-substances_in_fridge_freezers.pdf

This study found that advanced processes such as pyrometallurgy, hydrometallurgy, and electrochemistry were used to separate materials and recover valuable metals.[552] Further, the study established that electrostatic separators were adopted to extract plastics, particularly those with small particle sizes. Sand-based fluidized beds were also being researched to facilitate gravity separation. Additionally, magnetic separation and pyrolysis were significant technologies in the retrieval of carbon and dust. Notably, optoelectronic sorting is being developed to be used in separating materials during e-waste recycling.[553] Electromagnetic field techniques were developed with pulsed excitation and combined permeability and conductivity of every material to enable their segregation at low fields.

There were no records on similar technologies within the GCC member states. Since not much recycling was recorded, it was impossible to study the specific processes adopted by recyclers within the GCC member states. The lack of pre-processing technology proves that the GCC cannot achieve an e-waste circular economy. Most e-waste materials will be lost, and environmental harm will be caused where poor technique is used. Hence, the prospects of turning e-waste into gold within the GCC depend on developing appropriate technology for all the processes.

9.3 PUBLIC-PRIVATE PARTNERSHIP IN E-WASTE MANAGEMENT

This research studied the role of the government in ensuring an e-waste circular economy. The role of government was studied in two ways; first, the legislation passed to tackle e-waste and the government's role in collecting and recycling e-waste. The findings on the first role have

[552] Sahu, K. K., and A. Agrawal. "Processing of Electronic Waste (E-Waste)." (2008): 117-126.
[553] Kell, Darren. "Recycling and recovery." *Electronic waste management. The royal society of chemestry* (2009): 91-110.

already been discussed in Chapter 8 of this research. The study established collaboration between the government and the private sector in e-waste management. The government of Bahrain, for example, has set a charity project called Recycling-for-Charity project by partnering with an organization called the Universe Environment BSC.

Notably, there are other private initiatives across the GCC member states. This study found that the partnership initiatives were tailored towards encouraging the recycling of e-waste. Some of these initiatives discussed in Chapter 7 were to collect e-waste. However, it remains unclear how the government planned to turn the wastes into valuable commodities. The PPP initiatives did not establish clear targets, technology, and data on the materials recovered or collected for recycling. Notably, the private and government initiatives indicated the readiness of the GCC member states to embrace the 'Official Take Back System.' Only through an 'Official Take Back System' can the GCC governments establish clear guidelines and standards on e-waste recycling. Equally, the GCC member states can collect and track data on e-wastes then set targets within the region.

As it stands, this study revealed that the GCC is not adequately prepared to collect e-wastes through any public-private partnership or private initiatives. The initiatives within the GCC member states also failed to demonstrate adherence to international best practices in recycling e-waste. Based on these findings, the GCC cannot presently achieve an e-waste circular economy. Even if more initiatives were to be implemented by private entities and the government, the lack of standards on recycling would expose people to hazardous chemicals. Further, private entities may be more concerned with profit-making at the expense of environmentally sound recycling of the e-waste. Thus, the research concludes that although there are numerous initiatives to collect

and recycle e-wastes within the GCC member states, the governments must step in to regulate the conduct of those initiatives if at all the GCC states are to achieve a circular economy on e-wastes.

9.4 Conclusion on Possibility of E-Waste Circular Economy within the GCC Member States

The chances of achieving a circular economy through the recycling of e-waste within the GCC are minimal. Thus, the GCC cannot turn e-wastes into gold based on several findings that have already been discussed above. To turn e-waste into economically viable materials, the GCC needs to take several measures. Notably, turning e-wastes into economically viable material starts with the recognition of their hazardous nature. Whereas it is possible to recycle almost all electronic and electrical equipment, some equipment contains high levels of toxic materials. The toxic materials are usually labeled as focus materials in the R2 standards. Therefore, proper recycling of e-waste must proactively separate WEEE containing the focus materials and treat them to mitigate their hazardous nature. However, the GCC states lack such standards, indicating that recycling materials like batteries may cause irreparable harm to the environment and workers.

Secondly, there is a need to employ the right technology in the recycling of e-waste. After manual separation, the different components of each material are recovered by applying the best available technology. The global practices on best available technology on treatment of e-wastes include advanced processes such as pyrometallurgy, hydrometallurgy, and electrochemistry. However, the GCC did not display any advanced techniques of recycling electronics. The lack of advanced technology in the GCC member states showed that it is impossible to recover valuable materials from e-waste. Precious metals such as gold require advanced technology to recover, while mercury is highly toxic. Both metals are found in electronic equipment and require advanced

technology to recycle. Thus, the GCC states can only achieve an e-waste circular economy by investing in the right technology.

Chapter Summary

Chapter 9 summarized the findings of the studies in Chapter 2, Chapter 3, and Chapter 7 of the research. Chapter 2 studied the concept of the best available technology in the recycling of e-waste. Chapter 9 drew inferences from the global best practices in recycling. It further made findings specific to the GCC. Chapter 7 studied recycling e-waste within GCC states. Chapter 9 found that the GCC states have no elaborate technology on e-waste recycling compared to the global best practices. Thus, the research proved that the GCC is inadequately prepared for an e-waste circular economy. Chapter 9 analyzed findings in Chapter 3 and compared them to the studies in Chapter 7. The global best practices on standards showed a tendency of regulation of different aspects of e-waste recycling. However, the best practices were missing in the GCC member states.

The next chapter will highlight the different thoughts on how the GCC can achieve a circular economy using e-wastes. These discussions will be in the form of recommendations to the governments of the GCC member states. Further, the proposals will involve legislative frameworks, the best available technology, standards of recycling, and e-waste collection, separation, and recycling targets.

CHAPTER TEN

CONCLUSIONS AND RECOMMENDATIONS ON E-WASTE CIRCULAR ECONOMY WITHIN THE GCC

10.0 Introduction

This last chapter of the research summarizes the discussions on the study conducted through this research. The study investigated the possibility of an e-waste circular economy within the GCC. The study developed different measures of an e-waste circular economy which were then investigated at the international level and within the GCC. The indicators of an e-waste circular economy included the legal framework, quantities, and the use of the best available technology. The findings of this study have already been discussed at length in Chapters 8 and 9. Chapter 10 will now summarize the findings and discussions and conclude on whether the research objectives were met. This chapter is divided into two major parts. The first section discusses the conclusions of the research concerning the research objectives. The second part discusses recommendations for the GCC to implement a circular economy based on recycling.

10.1. Conclusions

The study focused on three main objectives. The first objective of the research was to study the possibility of an e-waste circular economy within the GCC member states. The research identified the global best practices on e-waste recycling and compared them with the practices within the GCC member states. The practices include the legal framework on e-wastes, environmental law principles including environmentally sound management of e-waste, and the best available technology in e-waste recycling. Further, the research investigated the legal and policy framework on e-wastes generally and recycling in particular. Globally, the research analyzed international conventions and treaties that regulate e-wastes and the different chemicals found in e-waste. The research then investigated the legal framework of the GCC member states

to answer the first question on whether the GCC states have an adequate legal framework for managing e-waste.

Chapter 5 investigated the relevant international and regional instruments relevant to waste electrical and electronic wastes. The study on these international and regional instruments was divided into two. The first section discusses international conventions such as the Basel Convention, 1989;[554] Stockholm Convention, 2001;[555] Minamata Convention, 2013;[556] Rotterdam Convention, 1998;[557] and the Montreal Protocol, 1987.[558] The second section discusses regional treaties that regulate the trade in hazardous chemicals and wastes. Treaties and directives from Africa, European Union, and South Pacific are discussed, including the Bamako Convention, 1998;[559] Waste Shipment Regulation (EC) Nº 1013/2006;[560] Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS) Directive, 2011;[561] Waste from Electrical and

[554] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (adopted 22 March 1989, entered into force 5 May 1992) 1673 UNTS 126. Available at: http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

[555] Stockholm Convention on Persistent Organic Pollutants (adopted 22 May 2001, entered into force 17 May 2004) 2256 UNTS 119. Available at: http://chm.pops.int/Portals/0/Repository/convention_text/UNEP-POPS-COP-CONVTEXT-FULL.English.PDF

[556] Minamata Convention on Mercury (adopted 9 October 2013, entered into force 18 May 2017) Available at: http://www.mercuryconvention.org/Portals/11/documents/conventionText/Minamata%20Convention%20on%20Mercury_e.pdf

[557] Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (adopted 10 September 1998, entered into force 24 February 2004) Available at: http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx

[558] Montreal Protocol on Substances That Deplete the Ozone Layer (adopted 16 September 1987, entered into force 1 January 1989) Available at: https://treaties.un.org/doc/Treaties/1989/01/19890101%2003-25%20AM/Ch_XXVII_02_ap.pdf

[559] Bamako Convention on the ban on the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa Layer (adopted 30 January 1991, entered into force 22 April 1998) Available at: https://au.int/en/treaties/bamako-convention-ban-import-africa-and-control-transboundary-movement-and-management

[560] European Union, *Regulation (EC) No. 1013/2006 of the European Parliament and of the Council on shipments of waste*. Available at: http://extwprlegs1.fao.org/docs/pdf/eur65175.pdf

[561] European Union, *Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment OJ L 174 of 1 July 2011*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011L0065

Electronic Equipment (WEEE) Directive, 2012;[562] Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) Regulation, 2006,[563] and the Waigani Convention, 1995.[564]

The study found that the Basel Convention applied to the GCC states through different decrees established by the GCC member states. However, information on compliance with the convention remained scanty within the GCC member states, as seen in Chapter 6 of this research. The Basel Convention was directly applicable to the management of waste electrical and electronic equipment. Notably, the convention regulates trade in hazardous wastes and clarifies the types of wastes, including waste electrical and electronic equipment (WEEE). The regulatory framework of the convention provides for the definition of hazardous wastes, transboundary movement of such wastes, and how state parties must manage such wastes. Article 2 defines wastes as substances and objects that have either been disposed of or intended for disposal.[565] The convention also allows state parties to define what each state may consider waste through their national laws.[566]

The second objective of the research was to assess the adequacy of the environmental laws, e-waste management practices, and current technology on recycling within the GCC. This research highlighted the different laws that GCC member states have enacted and their relevance in regulating e-wastes. Discussions in Chapters 6 and 7 on GCC's compliance with the Basel Convention found no specific laws on what the GCC states considered e-wastes under Article 3(1)

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[562] European Union, *Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02012L0019-20180704

[563] European Union, *Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) OJ L 396, 30.12.2006, p. 1–849*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R1907&from=EN

[564] Convention to Ban the importation into Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement of Hazardous wastes within the South Pacific Region (adopted 16 September 1995, entered into force 21 October 2001) Available at: http://macbio-pacific.info/wp-content/uploads/2017/08/Waigani-Convention.pdf

[565] Basel Convention, Art. 2.

[566] Basel Convention, Art. 3(1).

of the Convention. This finding led to the conclusion that the GCC lacks an adequate legal framework for e-waste management. The GCC must implement the basics of the Basel Convention by clearly defining what constitutes wastes in their territories to ensure proper e-waste management. Notably, the laws in the GCC were written in general terms and primarily related to marine and oil pollution. Whenever a law referenced hazardous chemicals or pollution, electrical and electronic waste were missing as a category with hazardous chemicals.

Moreover, under Article 1, the Basel Convention categorizes some wastes in Annex I as hazardous.[567] The domestic laws of member states may equally classify other wastes as hazardous. However, the classification needs to be deposited with the Secretariat within six months of ratifying the convention.[568] As already stated, there was no evidence from GCC member states on any deposition with the Secretariat to the Basel Convention on the domestic laws with additional classifications of hazardous wastes. The lack of such classification of wastes left the GCC vulnerable to transborder movement of electronic and electronic equipment waste. The WEEE may be disguised as goods intended for reuse as secondhand equipment from more developed countries. However, this study revealed inadequate data showing any severe threat of dumping wastes within the GCC.

The remaining conventions, such as the Stockholm, Rotterdam, Minamata, and Montreal Protocol, are specific to the chemicals listed under them. The conventions were relevant to the discussion of e-wastes since they regulate some chemicals and substances that are either used in the manufacturing or recycling of electronic and electrical equipment, including mobile phones, computers, and refrigerators. For instance, the Stockholm Convention regulates persistent organic pollutants (POPs) present in the plastic components of electrical and electronic equipment.

[567] Djahane Salehabadi (note 16) p. 10.
[568] Id.

Secondly, the Rotterdam Convention underpins the principle of prior informed consent in the regulation of hazardous chemicals. Minamata Convention espouses the ESM safeguards on human health and the environment when mercury is used to extract metals and manufacture electrical and electronic equipment. Chapter 6 and 7 of this research studied the extent of ratification and implementation of these other conventions within the GCC. The finding was similar to the one already made under the Basel Convention. Although the GCC states ratified most of these conventions through several decrees, there was limited information on how the requirements were implemented within the GCC to regulate the management of e-waste.

The study met the first and second objectives by investigating the legal framework on e-wastes at an international level and the GCC. The outcome of the research on the legal framework was that the GCC is inadequately prepared for an e-waste circular economy due to the lack of laws on e-waste management. Although the lack of a legal framework on e-wastes is not exclusively determinative of a circular economy, the study equally studied other merged variables in the following two objectives and the remaining research questions. Notably, the other variables studied were the best available technology in recycling e-waste, quantity flows, and trends in e-wastes. The trends studied as a determinant to the e-waste circular economy included the consumer trends in acquiring and disposing of electrical and electronic equipment. The trends in the collection of e-waste at the municipal and international levels were equally studied. For instance, the study investigated the chances of collecting and channeling e-wastes to recycling facilities. The research found that a circular economy was only possible with a proper legal framework, high consumption levels of electronics, high qualities of wastes, proper collection of wastes, channeling the wastes to recycling facilities, and the best available technology in recycling.

Each of these elements constituting a circular economy was investigated separately. Chapter 3 investigated the environmental law principles and standards. These principles are often contained in legislations and regulations that govern the management of wastes generally. The preventive and precautionary principles are at the core of waste management. They seek to minimize the potential harm resulting from projects by requiring environmental vigilance from concerned parties. Such due diligence can often be achieved by carrying out environmental impact assessments. However, environmental impact assessment is insufficient to minimize all forms of harm, especially hazardous wastes such as waste electrical and electronic equipment. As a result, other principles such as the extended producer responsibility (EPR) have emerged.

The EPR ensures that manufacturers bear the burdens of their product post-manufacturing. Manufacturers can discharge their responsibilities through a take-back system to ensure that the environment and humans are free from e-wastes. Additionally, this study investigated the extent to which the GCC states have embraced the environmental law principles and made findings in Chapter 6. The research found that although the GCC laws contained the general environmental law principles such as prevention and precautionary, other principles like the EPR were lacking. The GCC states did not have an elaborate take-back system to achieve the extended producer responsibility. Notably, the EPR ensures that that e-wastes are collected and directed to recycling. The lack of laws o regulations contributing to EPR was also a significant concern since the international best practices from the EU and USA indicated that EPR was grounded in regulations, as discussed in Chapters 3 and 5 of this research.

Another variable that is closely related to principles is the international standards for e-waste management. Chapter 3 studied several standards used globally in the recycling of e-waste. The standards identified in the research included the European Electrotechnical Committee for

Standardisation (CENELEC), the Waste Electrical and Electronic Equipment Label of Excellence (WEEELABEX), the Responsible Recycling (R2) Certification, the Electronic Product Environmental Assessment Tool (EPEAT), and the Swiss SENS/SWICO Technical Standard. International standards are essential in both product design and e-waste management. Notably, standards are critical in strengthening environmental regulation by ensuring that electronic equipment meets environmental safety requirements.

Further, standards promote safety and environmental protection. For instance, the standardization process establishes basic rules for the safe and environmentally-friendly management of e-waste and ensures that companies comply with the environmental safety rules. However, the GCC states lacked elaborate laws dealing with standards of recycling. Thus any recycling of products will pose more threats to the environment and human health than any economic value derived from the recycled products.

Besides the legal, regulatory, and policy framework, this research studied consumer trends and e-waste quantities. Chapter 4 studied the global quantities, while Chapter 7 studied the quantities within the GCC. The final objective of this research was to analyze data on e-wastes globally and within the GCC from 2014 to 2019. The level of e-waste generated was to determine whether there are sufficient raw materials in terms of e-waste for recycling. E-waste circular economy is dependent on high waste generation, population, and high consumption levels for electrical and electronic equipment. This research sought to study such trends and whether they favor the recycling of e-waste within the GCC member states. Chapter 4 revealed that the global levels have risen steadily since 2014. It is estimated that approximately 50 million metric tons of e-waste are produced yearly.[569] In 2016 alone, the Global E-waste Monitor 2017 noted that the

[569] *Global E-waste reaches record high, says new UN report*. (2020, January 17). TCO Certified. https://tcocertified.com/news/global-e-waste-reaches-record-high-says-new-un-report/

world generated a total of 44.7 million metric tons of e-waste, translating to per capita e-waste generation of 6 kilograms.[570]

The increase in global e-wastes quantities is attributed to different factors which constitute consumer trends. Technological advancements have increased the consumption of electrical and electronic products, fueling a rise in e-waste quantities. Equally, there has been a ready market for used electronic equipment in developing countries. The used electronics are affordable to most citizens for mobile money transfers and e-commerce transactions. Notably, the increased financial inclusion in the developing world has promoted the consumption of affordable electronics by middle and lower-income earners. Thus, secondhand devices such as smartphones, tablets, cameras, laptops, and home appliances have second and third lives in the developing world before reaching their end-of-life stage. This consumer trend in the developing world points to the possibility of high e-waste volume for possible recycling. The increased quantities at the global level favor the e-waste recycling business on two fronts. First, there is a constant turnover of raw materials for recycling. Secondly, there is uptake for recycled products by manufacturers. This trend in demand and supply of electronics leads to a circular economy of waste electricals and electronic equipment. The research finding was that the e-waste circular economy was possible at the global level due to the elaborate regulatory framework and constant flow in e-waste quantities.

This research also studied similar trends within the GCC states in Chapter 7. Similar to the global trends, the study found that the GCC states had high levels of e-wastes since 2014. However, there were no government records on imported or manufactured electronics within the GCC. Equally, there were no national data on e-wastes generated at the household and municipal levels.

[570] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.: *The Global E-waste Monitor 2017: Quantities, Flows, and Resources*, (UNU/ITU/International Solid Waste Association, 2017). https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

The research relied on international organizations' reports such as the Global E-Waste Monitor to develop statistics for GCC. This lack of data was attributable to the limited official take-back system or the Extended Producer Responsibility (EPR), as already discussed above. The research also found that the prevalent waste management techniques within the GCC were landfills and incineration. However, these two techniques are environmentally unsound and do not favor a circular economy of e-wastes within the GCC. The study thus partially fulfilled the third objective.

The last variable studied by this research was the use of the best available technology in e-waste recycling. The research found that a circular economy on e-waste is only achievable when the correct technology is used. Although there may be adequate laws, high quantities of e-waste, and other factors, recycling e-waste is only possible with advanced technology. Any obsolete technology is counterproductive to the environment and human health, undermining the viability of a circular economy. Globally, this research studied both pre-processing and end-processing treatment. Chapter 2 studied the different technologies used in pre-processing and recycling of e-waste. However, the GCC states lacked any pre-processing or end-product treatment technology. Therefore, this study concluded that the GCC states lacked the best technologies used to recycle e-waste.

In conclusion, this research fulfilled all its three objectives. The first objective was to study the possibility of an e-waste circular economy within the GCC member states. This objective was further divided into two. First, this research analyzed the adequacy of the environmental laws, e-waste management practices, and current technology on recycling within the GCC. Equally, it analyzed the data on e-wastes globally and within the GCC from 2014 to 2019. The level of e-waste generated was to determine whether there are sufficient raw materials in terms of e-waste for recycling. The research established that there are sufficient raw materials in terms of e-waste

for recycling. However, the GCC lacks an adequate legal framework to support a circular economy through e-waste recycling.

Additionally, e-waste management practices within the GCC states did not favor the recycling of materials in two ways. First, most collected waste ended up in landfills and municipal incinerators as opposed to recycling facilities. Secondly, the GCC states lacked an advanced technology to treat e-wastes and recover more materials from e-waste. Therefore, the study concludes that it is currently impossible to achieve an e-waste circular economy within the GCC member states.

10.2 Recommendations

The findings of this study have revealed a legal and technological gap within the GCC. Although there are adequate e-waste quantities within member states, there is no proper recycling of the same. The lack of recycling is attributable to inadequate legal framework and lack of modern technology within the GCC. This section thus makes recommendations on these two areas of legal framework and technology.

10.2.1 Legal Framework

The GCC member states should develop comprehensive e-waste legislation that incorporatess the environmental law principles to ensure effective recycling of e-waste. Adequate legislation requires five basics: clear objectives, definitions, roles and responsibilities, system design, and enforcement mechanism. Notably, the StEP Initiative, 2016 identified these salient features for effective e-waste legislation.[571]

[571] StEP Initiative, 2016. Guiding Principles to Develop E-waste Management Systems and Legislation. Solving the E-Waste Problem, Step White Paper. ISSN:2071-3576 (Online), 18.09.2021, Bonn Germany. https://www.step-initiative.org/files/_documents/whitepapers/Step_White_Paper_7_180221_low_compressed.pdf

10.2.1.1 Setting Clear EPR Objectives

The GCC states should include EPR-based legislation with a clear objective of reducing pollution and enhancing recycling. The EPR legislation should make producers responsible for the end-of-life management for products placed in the market. Besides, the legislation should also aim at improving the environmental performance of all operators involved in the life cycle of electrical and electronic equipment. Moreover, the legislation should reinforce an official take-back system which shall ensure that e-wastes are separated at the collection point and then channeled for proper treatment and recycling.

10.2.1.2 Internationally Aligned Definitions

Secondly, e-waste legislation in the GCC member states should have clear definitions of producers, recyclers, distributors, and other relevant stakeholders. The definitions should align with those found within the international e-waste regulations. The research showed that the GCC states have ratified or domesticated all the international conventions applicable to managing hazardous wastes, including waste electrical and electronic equipment. The domestication was done through decrees, but no legislation was passed to operationalize the various sections of the covenants. Therefore, the GCC states should consider revising their international commitments in tackling hazardous wastes, especially under the Basel Convention. A precise definition of terms and alignment to international e-waste regulations will help stakeholders understand the intent of the legislation and help in the environmentally sound management of wastes.

10.2.1.3 Provide Clear Roles & Responsibilities of Different Actors

The EPR-based legislation should provide for clear roles and responsibilities of each stakeholder. The legislations studied within the GCC states revealed that most laws referred to competent authority without clearly referring to a body or ministry. In some instances, there were partnerships between governments and private initiatives, yet there were no defined roles of the government and the private entities. Notably, states must define the roles of major stakeholders

such as producers, government, producer responsibility organizations (PROs), recyclers, informal actors, distributors, local authorities, and users to achieve an e-waste circular economy. The respective governments should publish a simple guidance document with a summary of the roles of different stakeholders.

10.2.1.4 Adequate E-Waste Management System Design

The EPR legislation within the GCC should cover all the elements required to make the e-waste management system clear, transparent, and enforceable. The legislation should address the setting up of efficient e-waste collection, reuse, and recycling system for optimal resource recovery and proper management of non-valuable/hazardous material. The legislation may not describe every element in detail but should create space for innovation and improvement. The collection model adopted in the legislation should be flexible and allow for formal and informal waste collection. For the formal collection model, the legislation should compel producers to set up, operate, and finance an efficient collection system. The laws should also allow a collection framework funded by producers and ensure that producer responsibility organizations (PROs) are in charge of actual collection.

Equally, the efficient collection framework envisaged in the legislation should provide incentives to informal collectors to ensure that the GCC states benefit from the highly efficient informal collection systems within the municipalities. The legislation must equally require all waste collectors to be registered and licensed as official collection points. The research revealed that most GCC laws had provisions for licensing of handlers of wastes generally. However, there is a need to make specific requirements for licensing e-waste collectors to ensure proper handling of hazardous components of waste electrical and electronic equipment such as batteries.

10.2.1.5 Clear Enforcement Procedures and Sanctions

Lastly, the EPR legislation within the GCC should set out the responsibilities of the government and enforcing authorities. All the previous four elements rely on enforcement by a higher authority for the legislation to achieve its mandate. Therefore, the EPR legislation must have clear procedures on what happens at each stage and the sanctions for non-compliance. Enforcement will entail establishing clear procedures for registration of producers, quantities placed on the market, and reporting requirements. Notably, this research showed that there were no official data on e-wastes within the GCC member states. This deficiency in the management of wastes can be addressed through better reporting procedures where each producer reports to a government agency on the volume of wastes collected and channeled for recycling. Equally, the legislation should provide the basis for procedures on licensing and auditing of dismantler and recycler operations to make sure that they follow environmentally sound management standards. This study revealed that the GCC states lacked proper standards for e-waste management. Thus, any possible recycling within the GCC would have severe pollution to the environment and human health. The challenge can be addressed by developing EPR legislation with precise enforcement mechanisms and standards for recyclers to ensure that their operation is environmentally sound.

Moreover, the legislation should provide for sanctions and penalties that are reasonable and proportionate to the offense. All the actors should be aware of the offenses created by the legislation. The responsible agencies must be adequately facilitated to enforce sanctions and penalties efficiently. Notably, the GCC member states had several environmental agencies and bodies established by decrees. Thus, the countries should synergize operations of key government agencies by allowing regular communications between environmental, customs, and port authorities and the e-waste register and PROs. Such communication shall ensure seamless monitoring and enforcement of the laws among different stakeholders.

10.2.2 Best Available Technology

Recycling e-waste is only achievable through the use of the best technology. Handling of e-wastes requires both pre-processing and end-processing treatments. Notably, the GCC states lacked modern technology-based recycling, justifying the a need to adopt the best available technology in the recycling of e-wastes through a government initiative or by private sector initiatives. Further, feasibility studies on the different technologies used in e-waste recycling should be conducted to identify the most efficient and cost-effective.

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