Doctoral Thesis

Life Cycle Assessment of Integrated E-waste Management Systems for Developing Countries: Assessment in Jordan

（途上国のための統合的電気電子機器廃棄物管理システムのライフサイクル評価:
ヨルダンでの評価）

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Abstract

E-waste (also known as Waste Electrical and Electronic Equipment; WEEE) is one of the fastest-growing waste streams worldwide. Given this rapid growth, major issues related to e-waste are a serious concern: (i) increasing amounts of e-waste pose detrimental effects to the environment and public health through improper recycling and final disposal, (ii) practices of informal recycling in developing countries are common, and recycling methods are rudimentary, and (iii) a significant portion of e-waste components ends up in unsanitary (uncontrolled) landfill and open dump sites. To address these issues, this dissertation sets the following objective: to evaluate the environmental impacts of the current improper e-waste management practices in developing countries in comparison with state-of-the-art technologies that can replace the existing inappropriate practices. To achieve the objective, this dissertation introduced a systematic approach in the Jordanian context to propose an integrated approach to e-waste management, IEWM (Integrated E-waste Management).

This dissertation comprises six chapters. In Chapter 1, e-waste management issues and related studies in developing countries and Jordan were reviewed, the research problem and research gaps were explained. Based on the problem statement, a systematic approach was designed to address the e-waste management related issues. In Chapter 2, the concept of Integrated Waste Management (IWM) was reviewed as a starting point for discussing proper waste management because it can contribute to figure out solutions to complex e-waste management issues. Therefore, seven topics related to IWM were discussed: (1) the emergence of the concept, (2) the definition of the concept, (3) harmonization of the concept with the waste management hierarchy, (4) planning for an adequate IWM system, (5) implementation of the concept in both developed and developing countries, (6) a comparison between the conventional approach and the integrated one, and (7) the analytical methods employed for planning and assessing IWM systems. Based on the discussions in Chapter 2, a definition and aims of IEWM approach in this dissertation were proposed, and the IEWM approach was introduced. IEWM suggested, the integration between both Municipal Solid Waste (MSW) and e-waste management systems is theoretically possible. That is because both systems share common waste fractions and treatment and disposal technologies.

The proposed IEWM suggested utilization for a suitable e-waste estimation method that is appropriate for developing countries as a first step. Therefore, in Chapter 3, pros and cons of five methods of estimating e-waste used in developing countries were examined, and applicability of these methods was discussed. Then, total and individual amounts of six appliances generated in Jordan, including both firsthand and secondhand of Electrical and Electronic Equipment (EEE), were estimated. Due to limited data availability in developing countries, the Consumption and Use (C&U) method has been widely employed for e-waste estimates. It was modified for its wider utilization for developing countries.

In Chapter 4, the concept of the IWM was applied to design nine Municipal Solid Waste Management (MSWM) alternatives for Jordan. Life Cycle Assessment (LCA) method was employed to evaluate the environmental impacts of the alternative systems, and they were discussed in comparison with the present system. The economic cost of the alternatives was also estimated. The goal was to identify the most environmentally-friendly and economically-viable alternative. The evaluations of MSWM was a necessity as a second step suggested by IEWM. That was because (i) e-waste stream in most of the developing countries is mixed with the MSW, and (ii) it is advantageous to utilize existing MSWM infrastructure. The results of Chapter 4 indicated that the scenario which utilizes the maximum theoretical recycling rate with waste separation at Material Recycling Facility (MFA), and sanitary landfilling of the remaining waste with energy recovery is the best regarding the environmental impacts and the cost. These results were employed for developing and evaluating e-waste management scenarios in Chapter 5.

The last step of the suggested IEWM approach is to estimate and evaluate emissions of e-waste practiced in the present situation in comparison with advanced management options. Thus, in Chapter 5, six scenarios for six EEE of e-waste handling were evaluated in relation to the present situation. These scenarios comprise three advanced technologies: recycling of materials, metals, precious metals, and incineration of plastic and hazardous waste, and sanitary landfill of the remaining waste. The scenarios were assessed for their potential to supplant the existing improper practices. The results of Chapter 5 showed that the best IEWM scenario was the one that features recycling of materials, precious and non-precious metals with a Material Recycling Facility (MRF) used for waste separation. Such a scenario also features incineration of plastic and Printed Circuit Boards (PCBs), and sanitary landfill of MSW and e-waste residues with the energy recovered from

incineration and landfilling. This evaluation was based on a semi-arid to arid climate conditions as seen in Jordan.

Chapter 6 provides the conclusions of this dissertation, its limitations, and the future studies. Overall, the results showed that the environmental impacts of e-waste are significantly high in the present situation. Among 70 examined cases for e-waste management for six EEE (mobile phone, laptop, CRT TV, LCD TV, washing machine, and refrigerator), the study concluded that the integrated technologies that should be paid attention are: recycling with an appropriate proportion of materials, metals (precious and non-precious) with waste separation of MSW at MRFs. Such technologies also include sanitary landfill of the MSW with energy recovered with a proper recovery efficiency. These technologies benefit for reduction of the environmental impacts. The results also indicated that composting or biogasification or both of the organic fraction of MSW are promising technologies for an IEWM system. Incineration of a burnable waste of the MSW stream is a technology that should also be paid attention in developing countries for an IEWM system with a proper efficiency of energy recovery. It notably minimizes the environmental impacts for an IEWM system. However, implementing an incineration technology would lead to increased cost of the overall system.

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List of Abbreviations

C&U	Consumption and Use
EC	Emission Category
EEE	Electrical and Electronic Equipment
EoL	End-of-Life
EPI	Environmental Performance Index
GWP	Global Warming Potential
IEWM	Integrated E-waste Management
IWM	Integrated Waste Management
JDoS	Jordan Department of Statistics
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
MENA	Middle East and North Africa
MFA	Material Flow Analysis
MRF	Material Recycling Facility
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
PCBs	Printed Circuit Boards
WEEE	Waste Electrical and Electronic Equipment
WFs	Weighting Factors

1. INTRODUCTION

1.1. Current E-Waste Management Issues in Developing Countries and Jordan

1.1.1. E-waste Management Issues in Developing Countries

E-waste (also known as Waste Electrical and Electronic Equipment; WEEE) is becoming one of the fastest-growing waste streams worldwide. E-waste is becoming a rising global concern due to its alarmingly increasing volume and its toxicity. It contains over 1,000 substances, many of which are toxic, and creates serious pollution upon disposal (Puckett et al., 2002). It also has detrimental effects on the environment & public health (UNEP, 2007, Herat and Agamuthu, 2012, Song et al., 2014, Baldé et al., 2015).

Examples of hazardous substances include cadmium, chromium, lead, and antimony (Puckett et al., 2002, Agrawal et al., 2004, Ahluwalia and Nema, 2007, Umesi and Onyia, 2008, SEPA, 2011, Kiddee et al., 2013); in which they require adequate recycling to protect human health and the environment. Valuable metals (ferrous metals, copper, and aluminum) and precious metals (e.g. gold, platinum, palladium, and silver) can be put back in the use chain through proper recycling. An added value is that energy consumption of the recovered metals is usually less than that of primary production (UNEP, 2013). The current global production of e-waste is estimated to be 41.8 million tons per year, with a 4 to 5 percent annual growth rate and 5.9 kg/person/year (Baldé et al., 2015). The substances in the e-waste stream pose significant threats to the environment and health if not dealt with properly. Safe management of e-wastes is becoming a major problem in many countries, in particular, developing countries (Herat and Agamuthu, 2012).

The production of Electrical and Electronic Equipment (EEE) is growing tremendously worldwide. This rapid growth is due to significant advances in the electronic development, information, and communication industry; changes in consumption patterns and consumers' lifestyles; short product lifespans due to technological innovations; and economic development (Terazono et al., 2006, UNDP, 2012, NSWMA, 2013, Needhidasan et al., 2014, Hossain M. et al., 2015).

Given this rapid growth, a major issue related to EEE is the improper management of its disposal which leads to significant environmental impacts (Babbitt et al., 2009, Herat and Agamuthu, 2012), including emissions of toxic substances to water, air, and soil. For instance, informal recycling sector in developing countries is common, and usually, the recycling methods are rudimentary with lax of environmental legislations (Tsydenova and Bengtsson, 2011). In some countries like China, e-waste is widely recycled by the informal sector (Chi et al., 2011). Besides informal recycling, controlled landfilling is often lacking in developing countries (Hoornweg and Bhada-Tata, 2012). In low-income, lower-middle-income, and middle-income countries, open dump accounts for 13%, 60%, and 32% respectively, and landfill 59%, 11%, and 91% respectively (Hoornweg and Bhada-Tata, 2012).

Developing countries are facing huge challenges in managing e-waste which is domestically generated or imported illegally as used products (Nnorom and Osibanjo, 2008). In many developing countries, particularly low-income and middle-income countries, a significant portion of e-waste components finds its destination to unsanitary (uncontrolled) landfill sites. Similarly, informal recycling of e-waste is widely practiced. Wires are burned in open spaces to remove plastic and recover copper. Acid extraction is also practiced to retrieve precious metals like gold, platinum, palladium, and silver from Printed Circuit Boards (PCBs). Such practices can be notably seen in China, India, Pakistan, Vietnam, Philippines, Nigeria, and Ghana, where the e-waste is disassembled by poor people using rudimentary methods to recover valuable metals and do not have facilities to safeguard the environment and health (Leung et al., 2006, SEPA, 2011). Figure 1-1 shows practices of improper handling of e-waste in China.

Open burning of wires and other parts to recover metals such as steel and Copper

Gold recovering from waste PCBs using acid baths

Waste from PCBs

Dumping of acid-treated PCBs

Figure 1-1. Examples of improper e-waste handling in China
(Source: Wang and Xu (2014))

Heeks et al. (2015) stated that developed countries differ from developing countries in respect to e-waste. The major issues in developing countries are: (1) threats from treatment are greater, (2) formal systems of recycling lack in most of the developing countries, and (3) legislations are weak or absent. Osibanjo and Nnorom (2007) pointed out five e-waste related issues in the context of developing countries: (1) the fast development of Information and Communication Technology (ICT) and its influence on e-waste quantities, (2) increasing e-waste generation quantities, (3) the components and materials of e-waste, (4) the management issues, and (5) the pollution from present management practices.

Several studies were conducted to address e-waste issues in both developed and developing countries. For instance, Menikpura et al. (2014) conducted a study to assess co-benefits of e-waste recycling of washing machines, refrigerators, air conditioners, and televisions in

Japan regarding greenhouse gas (GHG) reduction. Bigum et al. (2012) modeled the recovery of aluminum, copper, gold, iron, nickel, palladium, and silver from high-grade e-waste. Their study considered manual sorting, shredding, magnetic sorting, eddy-current sorting, and optical sorting. Studies like Noon et al. (2011) assessed waste from computer monitors in Seattle metropolitan region considering several options of treatment: reuse, recycling, sanitary landfilling, or hazardous waste landfilling. Socolof et al. (2005) studied 20 environmental impacts of the entire lifecycle of cathode ray tube and liquid crystal display of computer monitors. Wager et al. (2011) presented results of combined Material Flow Analysis (MFA) and Life Cycle Assessment (LCA) to calculate the environmental effects of the collection, pre-processing and processing of e-waste in Switzerland. Their study considered e-waste either incinerated in a Municipal Solid Waste (MSWM) incineration plant or landfilled.

Tsydenova and Bengtsson (2011), conducted a review study to summarize the existing knowledge of hazardous chemicals associated with e-waste recycling and the End-of-Life (EoL) treatment options for both developing and developed countries. Andrae and Andersen (2010) conducted a literature review for key LCA studies on consumer electronics. The focus was put on the Global Warming Potential (GWP) in different life cycles. Song et al. (2012b) employed LCA and investigated environmental performances of PCs in Macau considering the entire life cycle. Song et al. (2013) investigated environmental impacts of an e-waste treatment enterprise in China for TVs, PCs, air conditioners, refrigerators, and washing machines. Hischier et al. (2005) combined an approach of MFA and LCA to assess environmental impacts of two Swiss take-back and recycling systems. Several studies including Leung et al. (2006), Estrellan and Iino (2010), Jinhui et al. (2011), and Wu et al. (2015b) estimated emissions from informal recycling.

de Souza et al. (2016) aimed to assess sustainability and to prioritize system alternatives for e-waste management in Rio de Janeiro, Brazil. The work primarily focused on Multi-Criteria Decision Analysis (MCDM) with implementing LCA. The study introduced an approach to e-waste management scenario selection based on the MCDM. Hong et al. (2015) conducted an LCA to estimate the environmental impacts of e-waste from computer and TV and by considering two common scenarios in China: e-waste treatment with EoL disposal and without EoL disposal. The second scenario (without EoL disposal) considered e-waste is open burned. These two studies are based on a scenario approach. A comprehensive review of the existing studies addressing various topics of e-waste management can be found in a study by Perez-Belis et al. (2015). The review includes 350 studies focusing on environmental impacts of e-waste.

Other previous studies about e-waste in the context of developing countries addressed the below three points:

1. E-waste generation

   Estimating e-waste generation is the first step for the planning of its proper management (Alavi et al., 2015). It is also the first step to understanding its material flow (Lau et al., 2013). Examples of studies focused on the e-waste generation and the estimation methods are: Matthews et al. (1997), Crowe and Elser (2003), EEA (2003), Widmer et al. (2005), UNEP (2007), UNEP (2009), Araújo et al. (2012), Schluep et al. (2012), Lau et al. (2013), Wang et al. (2013), and Alavi et al. (2015). E-waste generation and the estimation of produced e-waste are one of the major issues studied in the literature. Perez-Belis et al. (2015) concluded from their extensive literature review there is a lack of standardized methods for e-waste estimation in several countries.

2. E-waste flow

   A required step for proper management of e-waste is to estimate its flow. Several studies aimed to estimate the flow of e-waste. Peralta and Fontanos (2006) estimated the flow of five electronic products from their generation as waste to the final destinations: reuse, storage, recycling, and landfill. The study employed the Carnegie Mellon University by Matthews et al. (1997). Andarani and Goto (2013) employed the MFA for the Indonesian context. The author’s findings showed that there is an indication that a large flow of reuse is currently happening. The major flow of e-waste was found to recycling and disposal processes is via reuse; because reuse can reduce a large number of e-waste that is potentially being generated.

Other similar studies are by Ibrahim et al. (2013), Jacob et al. (2014), Lau et al. (2013), Liu et al. (2006a), and Liu et al. (2006b).

3. Impacts to human health and the environment
   Regarding environmental impacts caused by e-waste, several studies are available. For instance, Xue et al. (2015), quantitatively assess the environmental impacts of processing PCBs recycling in a formal recycling chain. Song et al. (2012a), investigated the environmental performance of TVs in China by focusing on the cathode ray tube. The study considered the four life stages of the life cycle of EEE products: manufacturing, distribution, use, and EoL. Duan et al. (2009) applied LCA to investigate China's desktop personal computers on a global level for the whole life cycle. Most of the studies focused on the estimation of emissions from improper recycling mainly in informal recycling and on emissions to soil. For example, the study by Fujimori et al. (2012) reported concentration, enrichment factors and hazardous indicators of 11 metals in soil from formal and informal recycling from the soil in the Philippines. Other studies focused on the evaluation of the health and environmental impacts of emissions from e-waste, and mainly in the Chinese context. Examples of these studies include Lau et al. (2014), Leung et al. (2008), Song and Li (2015), Wu et al. (2015a), Xu et al. (2015), and Zheng et al. (2013).

The literature review that was taken in this chapter comprised 77 peer-reviewed articles and reports about e-waste management related issues and topics. In summary, the below are challenging issues of e-waste management in developing countries:

1. The generation of e-waste quantities is a major concern. This is due to the lack of infrastructure to manage e-waste appropriately. Moreover, the significance of secondhand EEE is a pressing issue due to the lack of verification of its functionality and its hazardous content.
2. In many developing countries, inventory assessment of e-waste is poor or does not exist.

3. The exported e-waste from developed countries to developing countries for recycling leads to a situation that EEE products become e-waste in developing countries, and it worsens e-waste management in those countries (ESDO, 2011).
4. The absence of knowledge in which the consciousness levels are weak near the toxic nature of e-waste.
5. The fact that e-waste is mixed with Municipal Solid Waste (MSW) and in which both are treated inadequately in most cases.
6. Deficiency of knowledge of human health and environmental impacts of the conventional practices of e-waste.
7. It is common that in many developing countries, there are no legislations to regulate and control the import and disposal of the generated e-waste. Such legislations, if exists, can diminish the hazardous nature of e-waste management in these countries.

1.1.2. E-waste Management in Jordan and Related Studies

Seitz (2014) analyzed the existing e-waste practices in ten countries of the developing Middle East and North Africa (MENA) region. The author concluded that e-waste is of rising concern in many of those countries and e-waste risks for human wellness and the environment from inappropriate e-waste management are not yet well known, and awareness is still low. Thus, this study focuses on this region; specifically on Jordan as it is a member of the MENA countries.

Jordan was selected among developing countries in the MENA region because the environmental performance of the country is presumably high in the region. For instance, the results of a recently published report by Yale Center for Environmental Law & Policy (YCELP) showed that Jordan ranked third in developing countries of the MENA region after Tunisia and Morroco, for its environmental performance (YCELP, 2016). The Environmental Performance Index (EPI) developed by YCELP ranks the performance of high-priority environmental issues in two areas: protection of human health and protection of ecosystems. Though the EPI does not include quality of waste management for the ranked countries; it provides insight on the environmental quality in each ranked country.

The report by the World Bank (2009) also stated that the environmental performance of the country is competitor comparing to other developing MENA countries. The country pays attention to environmental development and, thus, the potential of introducing advanced, integrated e-waste management options is predictably possible.

Jordan, like many other developing countries, is facing a challenge of managing e-waste. For instance, many informal recycling activities take place throughout the country according to the author's interview of two field trips to Amman and Irbid cities in August 2014 and 2015. The government concerned about its negative impacts on the environment including generation, collection, and treatment of e-waste as well as informal sector's illegal practices on e-waste. In response to this problem, the government set up plans to include full management of e-waste that implement collection, reuse, and recycling.

Seitz (2014) stated that there is no e-waste related data available in the Jordan, and a specific e-inventory assessment is not available. After the report had released, another study in the Jordanian context prepared in 2011 became available by UNDP (2011). The report aimed to assess the current situation from computer waste through a survey focusing on material flow, legal background, and stakeholders involvement; however; it addressed a theoretical background of the general e-waste situation in the country only. The report is still important in the sense it is a step towards proper assessment and planning of e-waste management.

In describing the final disposal of e-waste in Jordan, the report of UNDP (2011) stated that recycling activities were carried out by the informal sector for over than 20 years; ferrous metals, copper, and aluminum were recycling informally; and individual collectors recover copper from e-waste and sell it out to be export to Asia. Regarding PCBs, most of its hazardous constituent ends up in dumping sites. According to the same report, there is no specific procedure on how to treat and disposed of e-waste in the country. E-waste is mainly dumped with MSW in any of 20 existing landfill sites unless it is picked up by scavengers or individual collectors for recycling; and recycling is practiced under primitive conditions (UNDP, 2011).

Six studies addressed e-waste related issues in a Jordanian context. The first is by Fraige et al. (2012) measured the level of awareness towards e-waste and to estimate the domestic e-waste in the country. The second is by Tarawneh and Saidan (2012) aimed to establish an inventory assessment for Jordan's e-waste. The third is by Tarawneh and Saidan (2013) in which the authors attempted to examine the public responses and level of awareness of e-waste. The fourth is by Alsheyab (2014) where the purpose of the study was to determine the potential recovery of metals and precious metals from high-grade e-waste by conducting a mass flow of laptops computers. The fifth is by Abdulla and Al-Ghazzawi (2000) where the authors estimated methane emissions from open dumping sites in the country where e-waste is dumped. The last is by Abu-Rukah and Al-Kofahi (2001), in which the authors estimated the characteristics of leachate samples collected from one of the biggest landfill sites including emissions from heavy metals.

1.2. Objectives of This Dissertation

From the literature review conducted in Section 1.1; although many studies addressed several e-waste issues, still there is a lack of knowledge on environmental impacts of improper practices in developing countries, mainly from open burning, open dumping, and unsanitary landfilling of e-waste. Some of the reviewed studies estimated emissions on e-waste burning and primarily in the Chinese context. Therefore, three main research gaps can be stated:

1. There are no existing comparative studies that aimed to examine the applicability of the existing estimation methods of e-waste for developing countries. As Perez-Belis et al. (2015) stated, there is no standard method for e-waste estimation. Ongondo et al. (2011) stated "reported global quantities of WEEE seem to be grossly underestimated. There is a need for standardized methods and techniques to facilitate realistic estimates on amounts of WEEE generated in different countries". Therefore, a comparative study on e-waste estimation method was required.

2. A lack of comprehensive estimation of environmental emissions (to water, air, and soil) from open burning, open dumping, and unsanitary landfill of e-waste, considering different climate conditions (e.g. the semi-arid to the arid climate of Jordan). Therefore, limited knowledge exists regarding the extent to which management of e-waste through the traditional waste management practices, in which landfilling and incineration (open burning), have caused adverse impacts on the environment (Jang, 2010).
3. From the studies reviewed in Section 1.1, there is a lack of environmental assessment of e-waste management in developing countries. A study was required to consider all existing e-waste processes from open burning, open dumping, and unsanitary landfilling as well as alternative e-waste treatment processes that can replace the existing improper practices in developing countries. Such options should include the available technologies: sanitary landfilling, recycling of materials, recycling of metals, recycling of precious metals, incineration of plastic, incineration or landfill of PCBs with comparison with the existing improper practices.

Therefore, in order to contribute to mitigating the improper handling of treatment and disposal of e-waste and to facilitate development of e-waste management systems for developing countries, this dissertation set the following objective: to evaluate the environmental impacts and benefits of different e-waste management scenarios; with a comparison to the existing improper e-waste management practices in developing countries by following a systematic approach.

This objective will be achieved by proposing an approach to e-waste management for developing countries after reviewing the Integrated Waste Management (IWM) concept, and by employing the LCA method. In the first step, the IWM approach will be discussed as a starting point to discuss waste management issues. The second step is to discuss the e-waste estimation methods and employing a suitable method for e-waste estimation that is applicable for developing countries. The third step is to evaluate the environmental impacts and economic cost of the current MSWM practices in developing countries. That is important because e-waste is mixed with municipal waste in many of developing countries (Osibanjo and Nnorom, 2007, UNDP, 2011, Dwivedy and Mittal, 2012, Ibrahim et al., 2013). This dissertation, therefore, proposes that to establish an effective e-waste management system, developing countries can take advantages of using the existing infrastructure of municipal waste treatment such as waste collection, landfill sites, and recycling facilities. This dissertation also proposes that the common fractions of the two waste streams of MSW and e-waste can be treated, and residues can be disposed in sanitary landfill sites in which such an approach can achieve an integrated e-waste management.

This approach can be regarded as a systematic approach. The rationales of using a systematic approach are:

1. The complex nature of e-waste management in developing countries (e.g. open burning, open dumping, unsanitary landfilling, and lack of knowledge on their environmental impacts and lack of awareness of its toxicity).
2. The complex composition of the e-waste and associated multiple environmental impacts.
3. The necessity for examining the environmental impacts and economic cost of the overall waste management practices in developing countries.
4. A proper long-term plan for e-waste management systems is necessary with consideration of appropriate e-waste generation.

1.3. Structure of Dissertation

This dissertation comprises six chapters. In Chapter 1, studies on waste management issues in developing countries, as well as the MENA region and Jordan, were reviewed. The research gaps, the objective, and the structure of the study were explained. In Chapter 2, a literature review on the concept of the IWM was conducted. The aim was to discuss the concept and how it can bring environmental and economic benefits to developing countries. The similarities and dissimilarities between the IWM and the conventional waste management were discussed. A definition of IWM was also presented. An integrated approach to e-waste management was proposed. Next is to employ a suitable e-waste estimation method that is compatible with the situation in developing countries regarding data availability and market conditions. For this purpose, pros and cons of five methods of estimating e-waste were examined in Chapter 3, and applicability of these methods was discussed. In Chapter 4, environmental impacts of Jordan's MSWM were evaluated, and the cost was estimated. The goal was to identify the most environmentally-friendly and economically-viable alternative to the current situation. Based on the concept of IWM, as discussed in Chapter 2, and the LCA approach, the potential environmental and economic impacts of nine MSWM scenarios including those with alternative waste treatment technologies were evaluated with a comparison to the present situation. Chapter 5 presents results of estimating and evaluating emissions of e-waste practices compared to evaluating three advanced options (seven scenarios for six products) in which they can replace the existing practices. Chapter 6 provides the overall conclusion of the study, the limitations, and the future studies. The structure of the dissertation is illustrated as in Figure 1-2.

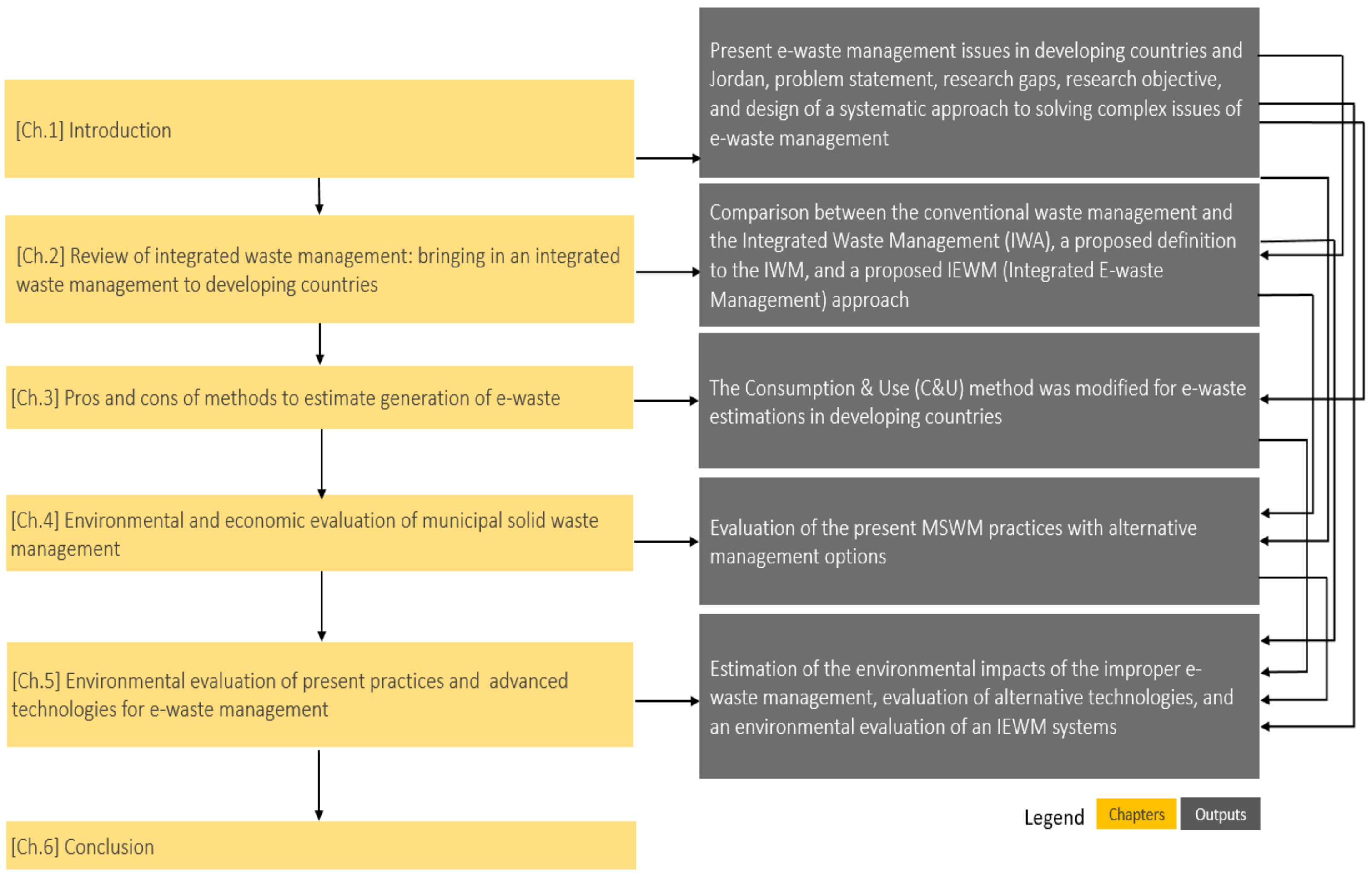

Figure 1-2. Structure of the dissertation

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2. REVIEW OF INTEGRATED WASTE MANAGEMENT: BRINGING IN AN INTEGRATED WASTE MANAGEMENT TO DEVELOPING COUNTRIES

2.1. Aim of this Chapter

Waste management is an area in which "integrated thinking" should provide a useful ground for integrated solutions. Specifically, the topic of integration and related elements in IWM. They have to be investigated to address the question of the challenges of waste management and how the integrated approach can solve such issues for modern societies. The situation that waste streams of MSW and e-waste are mixed in most of developing countries requires attention. Therefore, this chapter proposes a concept of integrated thinking for e-waste management in which it combines different waste streams, treatment and disposal methods to provide solutions to a certain waste management issue in a certain city, country, or region. The aim of the concept is to introduce a solution to the improper e-waste management in developing countries by bringing in an integrated e-waste management system to those countries.

2.2. Method

The procedure of the literature review is as below:

1. Journals for the review were selected.
    a. Sustainable Development (1993~2013/John Wiley & Sons/ Bimonthly).
    b. International Journal of Sustainable Development and World Ecology (1994~2013/ Taylor & Francis/Bimonthly).
    c. Environment, Development, and Sustainability (1999~2013/Springer/Bimonthly).
    d. Sustainability: Science, Practice, & Policy (2005~2013/ ProQuest/Biannual).

   e. Waste Management (2000-2015/ Elsevier).

2. A total of 222 articles related to IWM were obtained from the Web of Science by searching for “integrated waste management”.
3. The EndNote software was used for search based on the following keywords: “integrated”, “integrated waste management”,” “integrated solid waste management”, “integrated MSW”, “integrated municipal solid waste management”, “integrated MSWM”, “IWM”, and “integrated e-waste management” in the title, abstract, keywords, and the text. From the 222 articles, no articles were found that contains “integrated e-waste management” in the searched fields. Therefore, this query was omitted from the review process. A total of 57 articles were selected in which they discuss or apply the integrated approach.
4. Seven topics related to IWM were discussed: (1) the emergence of the IWM concept and its presence in the reviewed literature, (2) the definition of the concept through several points of view as appeared in the reviewed literature, (3) the harmonization of the IWM with the waste hierarchy for an modern waste management systems, including the processes of the IWM, (4) planning for an adequate and IWM system, (5) how the concept is implemented in both, developed and developing countries, (6) a comparative conclusion between the conventional approach and the integrated one, and (7) the analytical methods that employed for planning and assessing IWM systems. Finally, based on the discussion, a concept for integrated e-waste management systems for developing countries was proposed and referred as IEWM (integrated e-waste management).

2.3. Results: Bringing in an Integrated Waste Management to Developing Countries

2.3.1. Background of the Emergence of the Concept of IWM

The conventional waste management approach depends mainly on waste collection and final disposal. Historically, public health matters were the primary concern of waste management plans (McDougall et al., 2001). Waste issues in developing countries are aggravated by the malfunctioning of traditional waste management approach due to the rapid development. (Deshmukh et al., 2002). The traditional system of waste management affects not only the local environment and health but also the environment in neighboring areas (Murad and Siwar, 2007). Disposal of waste is a significant hazard because their improper methods of waste disposal make them a high-risk for infectious diseases (Murad and Siwar, 2007).

Waste problems are caused and worsen by increasing population, rapid urbanization, industrial growth and changes in consumption patterns in a complex way. The big amounts of waste generated and the availability of lands and the low costs are other factors for the traditional approach that depends mainly on landfills. For example, the average rate of landfill in African and MENA regions is 90% and 10% of informal recycling (Bahor et al., 2009). Another issue is that natural resources became scarcer, their availability is a major concern. This situation leads to a reconsideration of the traditional approach. These issues put emphasis on the fact that IWM is a necessary approach to getting into account waste recycling and to save natural resources. The IWM approach must deal with all these matters. It should be a holistic approach that can dish out with the waste issues. Such an approach must be considered when developing waste management systems for a particular municipality or country.

The results of the literature review showed that the vast amounts of waste consume energy for waste collection, which runs to an economic burden considering the limitation of energy resources. The report by Hoornweg and Bhada-Tata (2012) established that municipalities in low-income countries spend most of their budgets on waste collection services. Table 2-1 lists the amounts of waste generated worldwide by income. It is noticed that dumping and landfilling are the most practiced waste disposal in low-income, lower-middle-income, and middle-income nations (the developing world). In the example of the high-income nations, various methods are applied to treate waste (e.g. composting, recycling, and incineration).

Table 2-1. MSW disposal by level of income (million tons)
(Source of data: Hoornweg and Bhada-Tata (2012))

High-Income			Middle-Income		
Treatment methods	Amounts	Percentage	Treatment methods	Amounts	Percentage
Dumps	0.05	0%	Dumps	44	32%
Landfills	250	43%	Landfills	80	59%
Composting	66	11%	Composting	1.3	1%
Recycled	129	22%	Recycled	1.9	1%
Incineration	122	21%	Incineration	0.18	0%
Other	21	4%	Other	8.4	6%
Low-Income			**Lower Middle-Income**		
Treatment methods	Amounts	Percentage	Treatment methods	Amounts	Percentage
Dumps	0.47	13%	Dumps	27	49%
Landfills	2.2	59%	Landfills	6.1	11%
Composting	0.005	0%	Composting	1.2	2%
Recycled	0.02	1%	Recycled	2.9	5%
Incineration	0.05	1%	Incineration	0.12	0%
Other	0.97	26%	Other	18	33%

2.3.2. The Concept of IWM in Literature

The concept of IWM has invented in which the conventional waste management was no longer valid to meet the needs of today's societies. Today's world cities demand a waste management systems that goes beyond the concerns of public health. The concept of IWM received attention in the literature. For example, an earlier, and notably cited explanation of the concept was by McDougall et al. (2001). The authors also developed a tool for the use of Life Cycle Inventory (LCI) to support an integrated approach to solid waste management ((McDougall and Hruska, 2000)). McDougall et al. (2001) explained the concept of IWM as a system that must ensure human health and safety. It must be safe for workers and public health by preventing the spread of diseases. Besides these prerequisites, a sustainable system for solid waste management must be environmentally effective, economically affordable, and socially acceptable McDougall et al. (2001). EPA (2002) explained the IWM as “a comprehensive waste prevention, recycling, composting, and disposal program. An effective ISWM system considers how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment. ISWM involves evaluating local needs and conditions and then selecting and combining the most appropriate waste management activities for those conditions. The major ISWM activities are waste prevention, recycling and composting, and combustion and disposal in properly designed, constructed, and managed landfills. Each of these activities requires careful planning, financing, collection, and transport.”.

Shekdar (2009) explained the IWM as “the selection and application of suitable techniques, technologies, and management approaches to achieve specific objectives and goals.” Wilson et al. (2012) described ISWM as a framework “the ISWM framework distinguishes three dimensions for analysis of solid waste management and recycling systems: the physical system and its technological components, sustainability aspects (social, institutional, political, financial, economic, environmental, and technical) and the various groups of stakeholders involved”. According to the authors, the ISWM has three components: public health, environmental protection, and resource management. Seadon (2006) defined IWM as “an encompassing concept in which a framework is considered in an integrated manner which enables waste generators to utilize their waste streams more efficiently than just the disposal option. Applications of the components of IWM exist. There is wider scope for users to integrate fully media, agents, and tools to provide a waste management system that reduces the need for virgin materials, utilizes energy more efficiently, produces fewer emissions and thus has a lower environmental impact. The result of applying IWM to a system under consideration is the improvement of the sustainability of that system.”.

Wismer and Lopez de Alba Gomez (2011) described IWM as “an integral aspect of building sustainable cities and societies”. Rechberger (2004) stated the goals of the IWM: (1) to protect human health and the environment, (2) to conserve resources such as materials and energy, (3) to treat waste before disposal, and (4) to utilize the precautionary principle. Sabbas et al. (2003) defined the objective of IWM as “to deal with society’s waste in an environmentally and economically sustainable way.”.

The IWM is required mainly because various materials in the waste stream cannot be handled with a single waste treatment method (McDougall et al., 2001). A combination of treatment methods can manage waste in an efficient manner. Such treatment options include recycling, thermal treatment, biological treatment (composting and biogasification), and landfilling. Waste-to-Energy technology can also recover energy from waste in the form of electricity, such as incineration and gas recovery from sanitary landfill sites and incinerators or biogas plants. The integrated approach must be employed and integrated into municipalities’ waste management programs to harness the management options that can deal with waste related issues effectively. It was emphasized in the reviewed literature that the participation of stakeholders plays a crucial role in addressing waste management issues through the integrated approach (or integrated thinking) as it is a problem-solving approach to the most complex sustainability issues.

Established on the findings of the literature reviewed, the IWM was defined in this study as a systematic life cycle thinking approach that considers the entire waste management system, the waste hierarchy, and incorporation of different components of waste management from prevention to final disposal. It must aim to optimize the current waste management practices by achieving social acceptability, minimizing environmental burdens, and maximizing economic benefits. It must look at waste management schemes from all perspectives, including existing practices, waste management agenda or plans, society, stakeholder involvement, environmental and economic assessment. It must incorporate all of its ingredients including waste prevention, waste minimization, a well-established separation scheme, collection, transportation (including transfer stations) and treatment options (recycling, composting, biogasification, incineration, and landfilling) with consideration of material and energy recovery to select appropriate management options. Based on the current situation, a combination of the most suitable options can be combined to manage waste streams and to obtain benefits (environmental, economic, and social). The IWM also considers the current status of resources in a city or a country such as energy, materials, and land availability or scarcity.

2.3.3. Processes in IWM Systems

The concept of IWM should be harmonized with another important concept of waste management; the waste hierarchy, where the optimal case starts from waste reduction (prevention) followed by reusing of products. Then, recycling, composting and biogasification, and energy recovery from sanitary landfill sites and incinerators followed by sanitary landfill of residues. The traditional or conventional waste management schemes are founded on the final disposal of waste where waste prevention and recycling receive less care. On the contrary, the IWM approach, as well as the waste management hierarchy puts emphasis on diversion of waste from final disposal (e.g. reduce, reuse, and recycling; 3R).

An IWM system comprises several processes. They are as listed below:

a. Waste sorting at the point of generation and/or at Material Recycling Facility (MRF).
b. Waste collection schemes that consider the generation of waste quantities and their characterization.
c. Use of composting and biogasification to deal with the large amounts of disposing of organic waste of developing countries. Composting can produce fertilizers, and biogasification can produce energy.
d. An incineration technology in which it reduces the volume of waste and to recover energy from burnable materials. It can also be used for the treatment of hazardous waste.
e. Sanitary landfill to be utilized with leachate collection and energy recovery for disposal of residues from recycling, incineration, biogasification, and composting and disposal of hazardous waste.
f. Materials and metals recycling in which all types of recyclable wastes are taken into consideration.

The processes mentioned above in an IWM system should be examined environmentally and economically by the waste management situation and economic conditions for a certain municipality. These processes can be utilized in a combined way.

Based on the literature reviewed, the concept of IWM for MSW can be depicted with the waste management hierarchy as in Figure 2-1, and that for e-waste management as depicted in Figure 2-2.

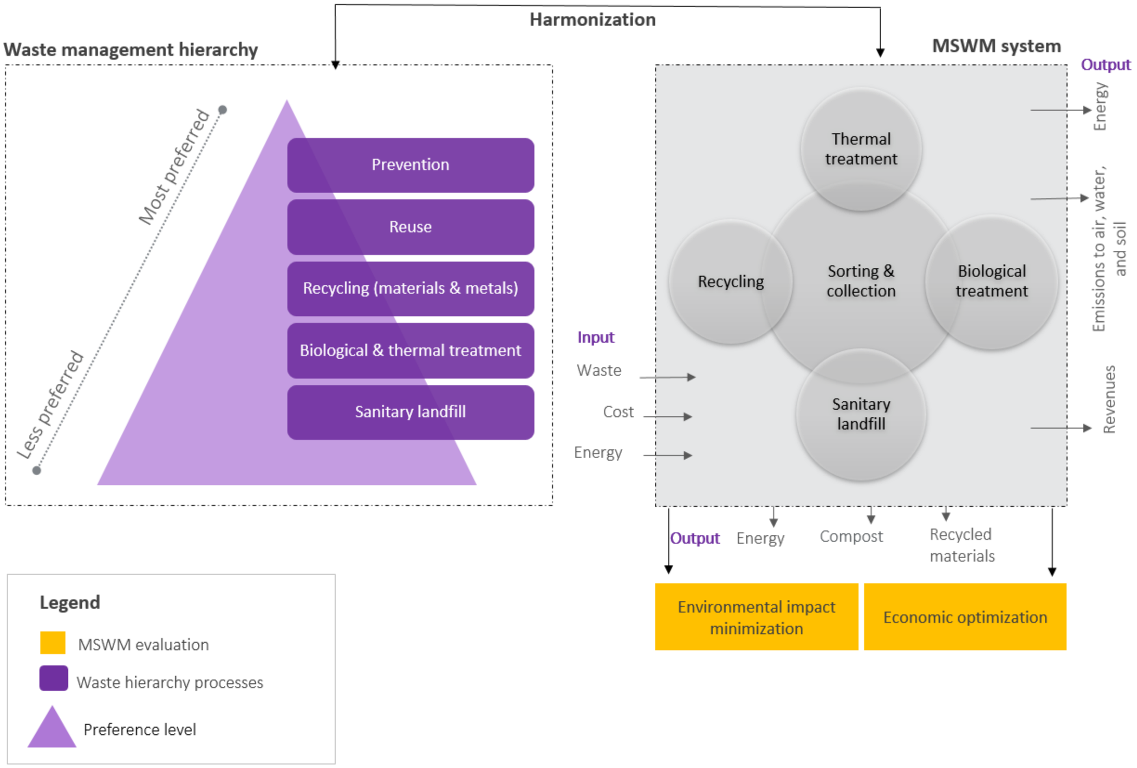

Figure 2-1. IWM for MSW

In the IWM system, recycling of materials (paper and plastic), recycling of metals (ferrous and non-ferrous metals), thermal treatment (incineration), biological treatment (composting and biogasification), and sanitary landfill are major processes and these are integrated with a proper waste sorting and collection systems.

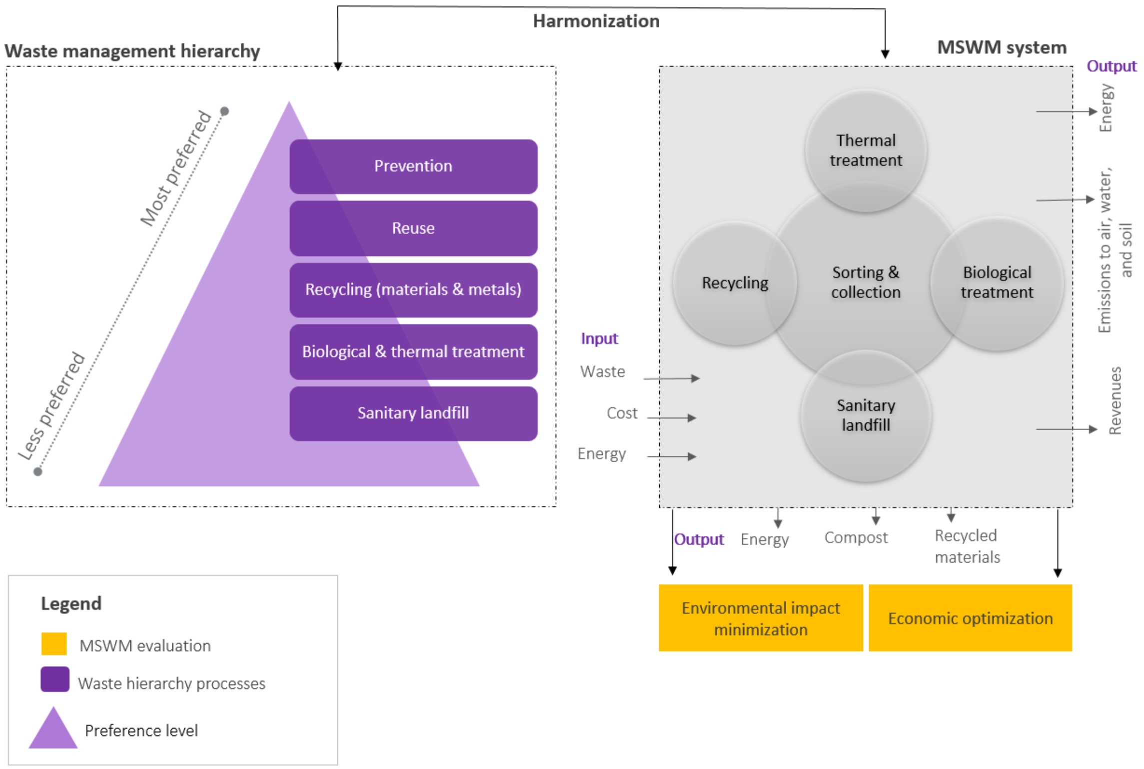

Figure 2-2. IWM for e-waste

In an integrated e-waste management, recycling of materials (plastic waste, paper packaging waste), recycling of metals (iron, steel, copper, and aluminum), recycling of precious metals (gold, platinum, palladium, and silver, etc.), thermal treatment, and sanitary landfill of residues are utilized. Among these components, several processes are common in both MSWM and e-waste management systems as shown in Figure 2-3.

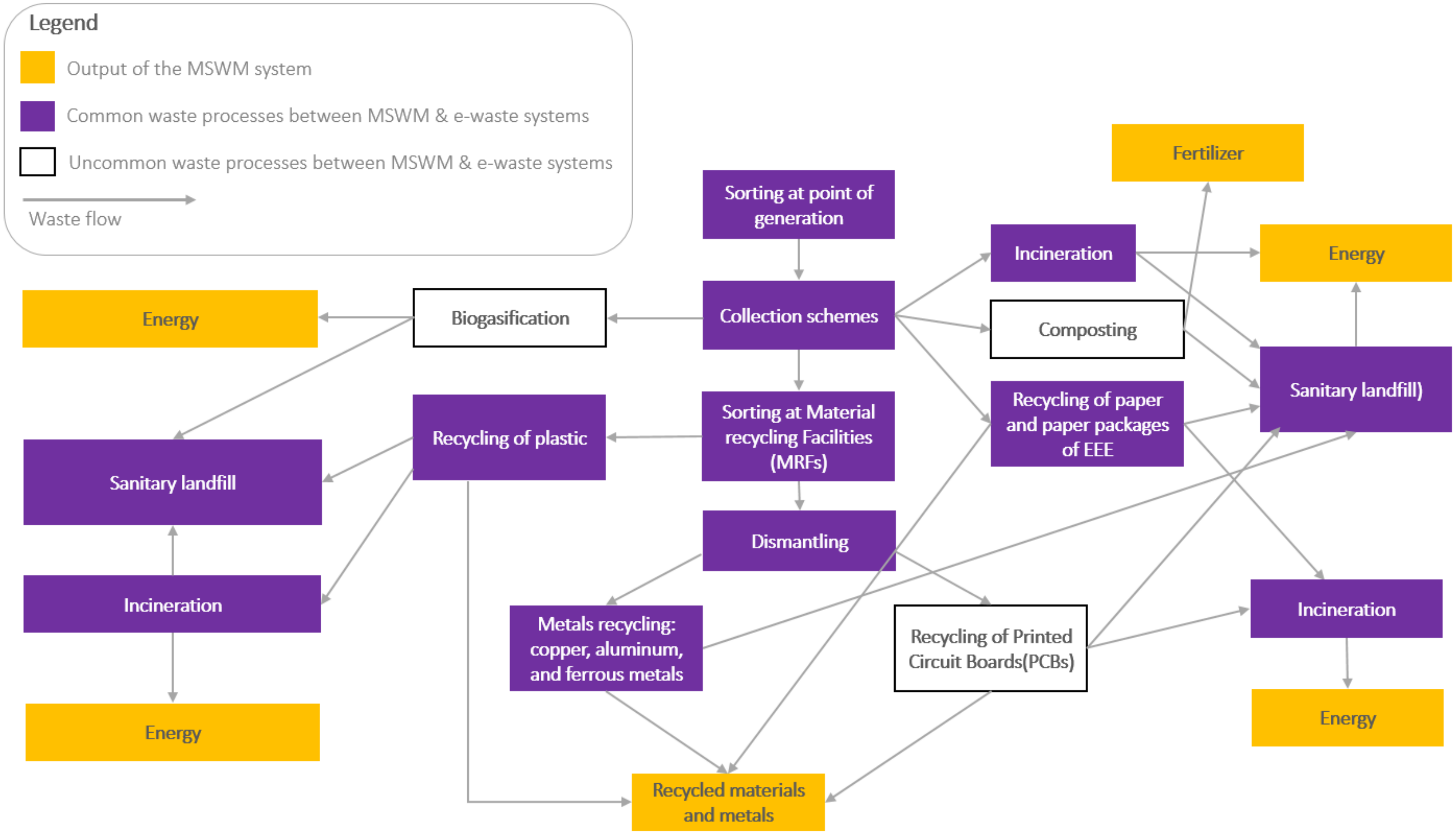

Figure 2-3. Common processes in an integrated MSWM system and e-waste management

Implementation of a suitable waste treatment and disposal method requires an understanding of waste composition (waste characterization of both MSW and e-waste), in which it can help to employ a suitable treatment technology for both waste streams. For the case of MSW, organic waste has a great potential to make compost or to utilize the biogas for electricity generation as it accounts for a high percent of MSW in developing countries. Paper and plastic (materials) are common fractions as well as aluminum, copper, steel and iron (metals) are common in both waste streams, and they can offer benefits when they are put back in the use chain. Precious metals are a different waste fraction between MSW and e-waste. They can be recycled in a recycling enterprise that deals with both the precious and non-precious metals. Nevertheless, a major concern of such an integrated system that should receive careful attention is the hazardous portion of the e-waste stream. Two possibilities for dealing with these waste are incineration and sanitary landfill. Later on in Chapter 5, both technologies are examined regarding their environmental impacts for the treatment of plastic waste and PCBs. The common and different fractions of MSW and e-waste are listed in Table 2-2.

Table 2-2. Waste streams of a waste management system

	Paper [1]	Plastic [3]	Hazardous Waste [2]	Metals [3]				Glass [3]	Textiles [1]	Organic [1]
				Copper	Aluminum	Steel	Iron			
Sanitary Landfill	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Recycling	✓	✓		✓	✓	✓	✓	✓		
Biogasification										✓
Composting										✓
Incineration	✓	✓	✓						✓	✓

[1]: MSW stream

[2]: E-waste stream

[3]: Common stream (MSWM and e-waste)

2.3.4. Planning for IWM and Estimation of Waste Generation

Planning for IWM requires consideration of various aspects of waste management including political, socio-cultural, economic, environmental, and stakeholder involvement (Schubeler, 1996). For the case of MSWM, Memon (2010) identified seven essential steps towards integrated MSWM planning including: data collection and analysis, information gathering on the current waste management system, setting of targets, identification of concerned issues with local stakeholders, financial, technical, environmental and social aspects, development of integrated of MSWM plan, development of an implementation strategy, and development of a monitoring and feedback system. From a technical view, planning of integrated MSWM should start with analyzing the current waste management situation in a certain city or country. Data is required for waste composition, quantities, transportation, energy, and material flow of waste (i.e. quantities go to landfill, recycling, composting, etc.). Various criteria to be taken regarding data collection: availability, reliability, range of data, and suitability for the estimation method (UNEP, 2007). Estimation of waste generation is the first step with a future projection to plan cautiously for a future system, considering the capacities of existing waste treatment facilities (e.g. the capacity of landfills).

Estimation of e-waste quantities is also a crucial step for planning for an integrated IWM. This should start by acquiring reliable data to determine the waste characterization (fractions of EEE). Estimation of e-waste generation is a required step for selection of an appropriate e-waste management treatment and disposal options. Therefore, e-waste estimation methods for developing countries were discussed in Chapter 3.

2.3.5. Implementation of IWM in Developed and Developing Countries

It was interesting in the review process to look at the topics of waste management research in both developed and developing countries. For the case of developing countries, the main problems that received attention were those of collection and waste treatment. Developed countries mostly focus on research and implementation of zero-waste and waste-to-energy plans. The IWM concept is being researched in developing countries but rarely utilized and defined, while it is implemented for the case in developed countries. This can be attributed to the fact that developed countries have already established their IWM plans that meet current and future situations.

The main concern in developing countries, especially low-income countries, is waste collection and managing landfill sites as they are the major and the most preferred waste disposal method. Developed countries have already implemented waste management plans. Such plans considered the most pressing issues and typically can manage adequately waste including educational and public awareness schemes, waste separation at source, proper collection systems, waste disposal options, and implementing waste-to-energy schemes. Although it was observed that many studies in the context of developing countries tend to review the current practices of MSWM, there was in increasing trend of the focus on the environmental impacts of MSWM in those countries. Table 2-3 shows example studies on MSWM in both developing and developed countries with various income levels.

Table 2-3. Example studies on MSWM in both developing and developed countries[1]

Author	Research aspects	Geographical location	Income level
Bianchini et al. (2011)	Material and energy recovery	Italy	HI
Giugliano et al. (2011)	Material and energy recovery	Italy	HI
Massarutto et al. (2011)	Material and energy recovery	Italy	HI
Blengini et al. (2012)	Glass recycling	Italy	HI
Tulokhonova and Ulanova (2013)	MSW management scenarios	Russia	UMI
greeZotos et al. (2009)	Developing holistic strategies for MSWM	Greece	HI

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[1] Income level: Based on Gross National Income (GNI) and the classification of Word Bank. 2016. *New Country Classifications* [Online]. Available: http://data.worldbank.org/news/new-country-classifications-2015 [Accessed June, 3 2016]. as July 2015. Low-income is defined as those countries with a GNI per capita of $1,045 or less; middle-income economies are those with a GNI per capita of more than $1,045 but less than $12,736; high-income economies are those with a GNI per capita of $12,736 or more. Lower-middle-income and upper-middle-income economies are classified at a GNI per capita of $4,125 (Word Bank, 2016b). HI denote "high-income"; UMI: "upper-middle-income"; LMI: "low-middle-income"; LI:" low-income".

Author	Research aspects	Geographical location	Income level
Geng et al. (2007)	Planning for MSWM	China	LMI
Greene and Tonjes (2014)	Quantitative assessments of MSW using indicators	USA	HI
Horio et al. (2009)	Energy recovery and CO_2 reduction	Japan	HI
Joseph et al. (2012)	Analyzing the waste generation, collection, and disposal	India	LMI
Bovea et al. (2007)	Environmental factors in the integration of in the integration of a transfer station	Spain	HI
Cifrian et al. (2013)	Carbon footprint	Spain	HI
Hong et al. (2010)	Scenario-based analysis of MSWM	China	LMI
ThiKimOanh et al. (2015)	MSWM strategies	Viet Nam	LI
Masood et al. (2014)	Assessment of MSWM	Pakistan	LMI

Author	Research aspects	Geographical location	Income level
Seng et al. (2011)	Review of MSWM	Cambodia	LI
Sharholy et al. (2008)	Review of MSWM	India	LMI

2.3.6. Comparison Between the Conventional Waste Management and the IWM

The findings of the literature reviewed showed that the conventional waste management particularly focuses on efficient removal of waste from a living environment and protection of human health. The approach is through disposing of the waste in a traditional way in dump or landfill sites. Though in many developing countries, sanitary landfill is limited and unsanitary landfill and open dump are widely observed practices. Therefore, no advanced elements of waste management (e.g. formal recycling and incineration) are utilized in the conventional waste management of the developing countries' MSWM systems. Assessing the environmental impacts of the current waste management practices with consideration of examining promising technologies are rarely seen. Similarly, an economically-viable waste management is rarely analyzed for alternative options. In some developing countries, waste treatment technologies such as sanitary landfilling with energy recovery, biogasification, and composting are practiced. Municipalities usually estimate and evaluate the cost and revenues of a current waste management system, but rarely evaluate the potential introduction of advanced technologies. Regarding reuse of products, secondhand products of e-waste are widely practiced in developing countries in which the conventional approach are widely employed while waste reduction is rarely seen. A major difference between the two approaches that the conventional one does not look at the e-waste stream and therefore, planning for a waste management that considers the inadequate practice of e-waste management cannot be seen partially or in literature. Table 2-4 compared to the conventional waste management and the IWM regarding various practices.

Table 2-4. Comparison between the conventional waste management and IWM

Practices	Conventional waste management	IWM
Utilization of various waste options	Partly yes	Yes
Environmental evaluation of the current waste management	Yes	Yes
Economic assessment of the current waste management	Yes	Yes
Economic evaluation of alternative waste management options	No	Yes
Waste characterization, estimation, and planning	Yes	Yes
Waste reduction	Partly yes	Yes
Reuse	Partly Yes	Yes
Planning for e-waste management with MSWM	No	Yes

2.3.7. Analytical Methods for IWM

By looking at the methods used to research waste management issues for both cases, developed and developing countries; LCA appears to be one of the major methods used. Other methods include employing statistical analysis and mathematical modeling, besides theoretical methods. Table 2-5 shows example studies that followed the IWM approach. The LCA method is used to measure environmental burdens of waste management processes (e.g. sorting, collection, recycling, and final disposal). Also, to compare among different waste management options for a particular municipality or country. LCA is a well-established environmental impact assessment method (ISO, 2006, Chang and Pires 2015). It is widely employed in the reviewed literature to evaluate the entire life cycle for certain product or system. With waste management, it can examine and assess the environmental burden of waste from the point of generation to the final disposal. According to Guinée and Jeroen (2002), LCA is defined as "compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle".

There are several LCA computer-aided tools were developed to help plan and assess IWM systems and they feature user-friendly interfaces. Such tools include, but not limited to, IWM-2 by McDougall and Hruska (2000), EASETECH model by Clavreul et al. (2014), the Co-benefits Evaluation Tools for MSW by Dashti and Doll (2014), and the WRATE software[2]. Commercial data of LCI that can be used to evaluate IWM processes and systems are listed in Table 2.6.

By considering data input for methodologies issues in the research of the most waste management problems, developing countries suffer from data unavailability. Conducting questionnaires and surveys usually overcome such difficulties, though the results often have limitations. For the case of developed countries, data is available in most studies in which it is utilized in various aspects (e.g., examining collection schemes, estimation methods for both MSWM and e-waste, modeling of the environmental impacts and cost, and models to the prediction of future amounts of waste).

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[2] http://www.wrate.co.uk

Table 2-5. Example of IWM-based analysis in studies

Title	Author(s)	Method or Approach	Geographical location	Income level
Application of life cycle assessment (LCA) for municipal solid waste management: a case study of Sakarya	Erses Yay (2015)	LCA	Sakarya	UMI
Assessment of municipal solid waste management scenarios in Irkutsk (Russia) using a life cycle assessment-integrated waste management model	Tulokhonova and Ulanova (2013)	LCA	Russia	UMI
Developing a common framework for integrated solid waste management advances in Managua, Nicaragua	Olley et al. (2014)	A framework to guide the evolution of the municipal solid waste management	Nicaragua	LMI
Environmental assessment of the Integrated Municipal Solid Waste the management system in Porto (Portugal)	Herva et al. (2014)	LCA	Portugal	HI
Improving integrated waste management at the regional level: The case of Lombardia	Rigamonti et al. (2013)	LCA	Lombardia	HI

Title	Author(s)	Method or Approach	Geographical location	Income level
Integrated approach to solid waste management in Chennai: An Indian metro city	Joseph et al. (2012)	Review	India	LMI
LCA of integrated MSW management systems: Case study of the Bologna District	Buttol et al. (2007)	LCA	Italy	HI
LCA of local strategies for energy recovery from waste in England, applied to a large municipal flow	Tunesi (2011)	LCA	England	HI
Life cycle assessment of integrated municipal solid waste management systems, taking account of climate change and landfill shortage trade-off problems	Tulokhonova and Ulanova (2013)	LCA	Japan	HI
Life cycle assessment of integrated waste management systems for alternative legacy scenarios of the London Olympic Park	Parkes et al. (2015)	LCA	United Kingdom	HI

Title	Author(s)	Method or Approach	Geographical location	Income level
Perspectives for integrated municipal solid waste management in Thessaloniki, Greece	Papachristou et al. (2009)	Analysis based on results of existing research programs investigating the evolution of MSW	Greece	HI
The holistic impact of integrated solid waste management on greenhouse gas emissions in Phuket	Liamsanguan and Gheewala (2008)	LCA	Phuket	UMI

Table 2-6. LCI databases

Database name	Provider
The ecoinvent database	ecoinvent center
The professional database by thinkstep	thinkstep
NREL database	National Renewable Energy Laboratory (NREL)
LC-Inventories.ch (updates and extentions to ecoinvent database)	ESU-services
ELCD	European Reference Life Cycle Database
ProBase+[3]	German Federal Environment Agency
DataSmart	EARTHSHIFT

Based on the reviewed literature, this study employed the LCA approach for environmental evaluation of both MSWM and e-waste systems in developing countries. The study followed a scenario-based approach to design various MSWM and e-waste management scenarios (as will be explained in Chapters 4 and 5) considering the IWM concept. The objective of this scenario-based approach is to examine different waste management options to tackle the improper management of e-waste in developing countries. The approach in this work is grounded on the systematic procedure as explained in Section 1.2. For the purpose of this study, it was needed to review how the LCA method is employed in both developed and developing countries for its utilization for the objective of this study.

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[3] Available in german

2.4. A Proposed Integrated Approach for E-Waste Management for Developing Countries

Based on the literature conducted in this chapter, this study proposes an integrated approach to managing e-waste in the context of developing countries. This approach is referred to in this study as Integrated E-waste Management (IEWM). The proposed IEWM approach aims to:

1. Tackle the issue in which both MSW and e-waste streams are mixed,
2. Utilize the existing MSW infrastructure to deal with both waste streams, and
3. Achieve environmental and economic benefits.

The proposed IEWM approach is defined as “a systematic and holistic approach that utilizes and integrates existing municipal waste and e-waste management. Its aim is to mitigate the environmental and economic burdens of e-waste by following the IWM concept and utilizing the LCA method.”. This approach is regarded as a “holistic” approach because it considers the waste management hierarchy as described in Section 2.3.2. It is regarded to as a “systematic” approach because it considers the integrity of waste management system from production or import to EoL and by considering each stage and phase.

The IEWM approach can be divided into two stages as depicted in Figure 2-4. The first stage includes three phases: sales of products, consumption of products, and waste generation (MSW and e-waste). The second stage is the EoL in which it includes two phases: “collection” and “treatment and disposal”, i.e., post-consumer stages.

This study proposes that, to establish an IEWM system, four major steps are to be taken:

1. Determination of the composition of municipal waste and e-waste,
2. Estimation of the quantities of municipal waste and e-waste,
3. Environmental evaluation of the existing MSWM systems with alternative treatment and disposal technologies, and evaluation of the cost of the present situation and the alternatives, and

4. Environmental evaluation of the present e-waste management practices with comparison with evaluation of available state-of-the-art technologies.

For MSW characterization at the first step, MSW is usually characterized by sampling and laboratory analysis of municipal waste. Examples of studies that followed this approach include Chang and Davila (2007), Chang and Davila (2008), Gomez et al. (2008), and, Younes et al. (2013). Estimation of MSW is less sophisticated compared to e-waste. MSW can be estimated by simply measuring a load of trucks that enter transfer stations or a landfill site. For example, the study done by Zeng et al. (2005) followed such an approach. The author’s interviews in a field trip to Jordan in 2014 observed this approach was followed in Jordan. Therefore, this study focused on e-waste estimations in Chapter 3 rather than MSW estimations. At the second step, estimation of e-waste quantities is more complicated as it is not easy to analyze or measure the e-waste quantities. Two reports can be referred to for detailed information on establishing an e-waste assessment for a certain city or country. The reports are UNEP (2007) and Schluep et al. (2012).

A precise method is required with suitable and a quality data. The waste composition of e-waste can be determined by conducting questionnaires as seen in the studies by Fraige et al. (2012), Tarawneh and Saidan (2012), and Saidan and Tarawneh (2015). Regarding the third and fourth steps, the environmental and economic evaluation of MSWM are presented in Chapter 4, and the environmental evaluation of IEWM systems is provided in Chapter 5.

The IEWM approach proposed to put emphasis on the second stage (the EoL) in which the improper handling of e-waste takes place, while it considers the entire life cycle of e-waste from import or production of EEE to the final disposal of e-waste. Regarding waste collection, the approach suggests the below waste collection schemes:

Collection:

i. A collection of deposit containers and collection with drop-off center.

ii. A collection of deposit containers.

MRFs:

iii. Sorted recyclables MRF, manual or mechanical.

iv. Mixed recyclable MRF, manual or mechanical.

For a selection of a proper scheme, selection criteria include waste composition (e.g., fractions of recyclable and burnable), daily quantities of waste generated, and the contribution of e-waste to an MSW stream. The integrated components of IWM for an IEWM are sorting at the point of generation or MRF, collection, recycling of materials and metals (precious and non-precious metals), composting, biogasification, incineration, landfill, and energy recovery. These components are proposed for an IWM as seen in Chapter 2.

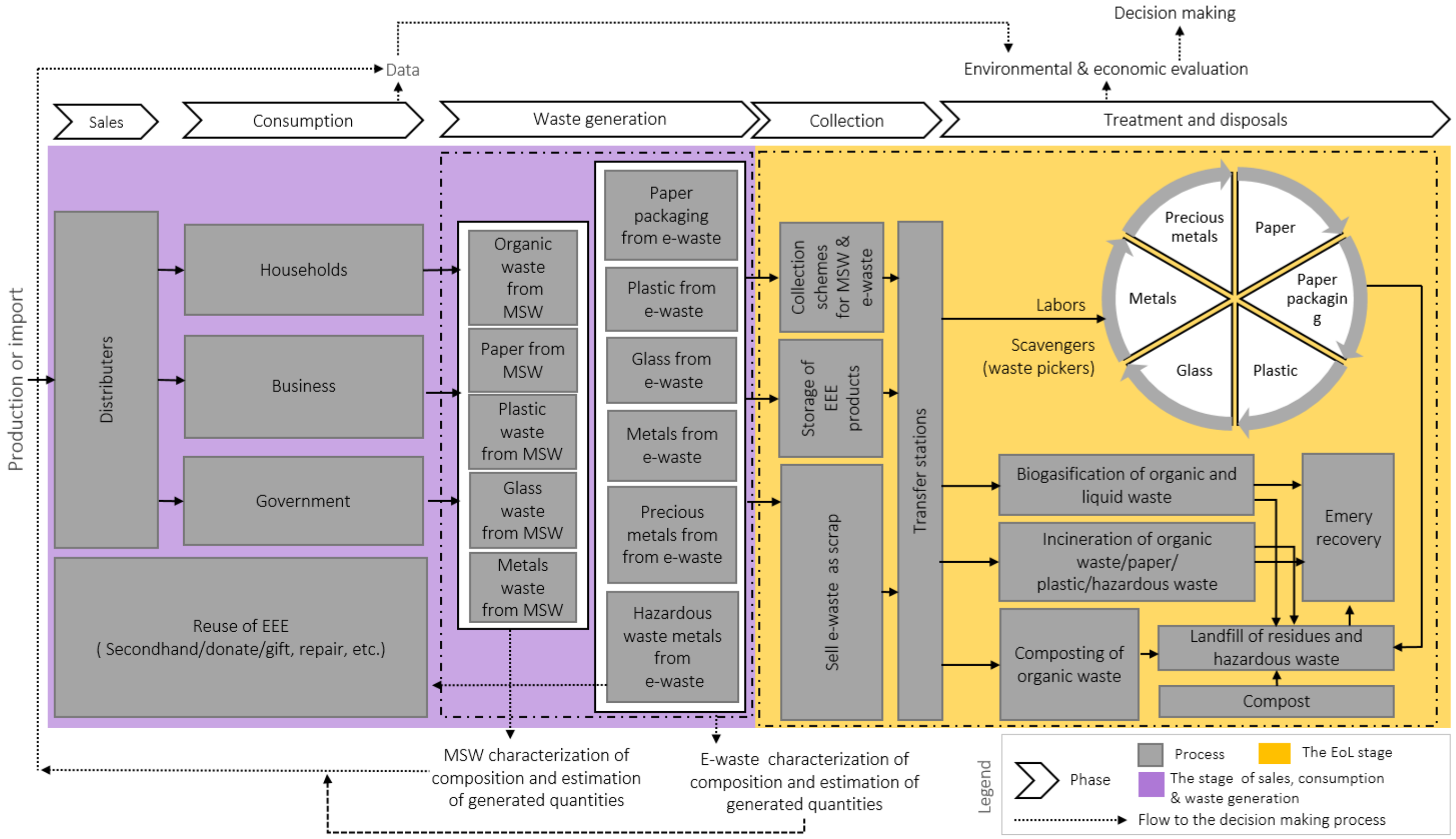

Figure 2-4. A proposed approach of Integrated E-waste Management (IEWM)

2.5. Conclusion of Chapter 2

IWM is an emerging concept in many developing countries. Many researchers tend to use the term “IWM” without a clear definition while utilizing the concept from a technical aspect rather than to define it. Defining the concept is significant because it differentiates between both the traditional and the integrated concepts and it facilitates the concept’s development and its implementation. IWM must supplant the traditional approach to respond to the demands of today’s modern societies. The traditional MSW approach is no longer able to deal with waste related complex issues and cannot achieve proper effective waste management. The IWM approach incorporates diverse processes of MSW to achieve social acceptability, environmental and economic optimization.

Both MSWM and e-waste management share common waste treatment and disposal processes. Therefore, the integration between both waste management systems is possible theoretically. Introducing an integrated e-waste management system can take advantages of the existing infrastructure of MSWM. Thus, it can be combined with e-waste to achieve and IWM system.

This study proposed a systematic and holistic approach to coping up with the e-waste management issues in developing countries (referred to as IEWM). The approach suggests to puts emphasis on the EoL of EEE products in which the improper handling of e-waste takes place, while it considers the entire life cycle of e-waste from import or production of EEE to the final disposal. In Chapters 4 and 5, the proposed concept of IEWM, especially the part of integrated treatment/disposal methods and integrated waste streams (the second stage), are to be used to set alternative scenarios of e-waste management. Although the proposed IEWM covers the elements of waste prevention and reuse, they are not used in these chapters for scenario settings.

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3. PROS AND CONS OF METHODS TO ESTIMATE GENERATION OF E-WASTE[4]

3.1. Aim of this Chapter

Estimation of the amount of e-waste generation is a crucial step for planning and evaluation of an IEWM system. This chapter examines the currently employed methods for e-waste estimations in developing countries. Five e-waste estimation methods will be compared with an inventory analysis for six EEE (mobile phones, laptop computers, desktop computers, TVs, washing machines, and refrigerators). Inventory analysis, here, refers to analyzing each method based on the data used to create e-waste inventories (mainly, the amounts of generated e-waste). These data include for each EEE (1) production, import, and export, (2) sales and stock in use, (3) the fate (reuse, recycle, storage, and landfill), (4) average weights and lifespans, and (5) penetration rates. The word "inventory" refers to characterization and generation of e-waste quantities. Inventory analysis examines both the used data in each method and their assumptions. It examines what conditions and under what assumption each method can be applied.

The purpose of the comparison is to understand the advantages and disadvantages of the methods that have frequently been used to estimate e-waste for their application to developing countries. Thus, (1) different e-waste estimation methods will be compared and (2) current e-waste generated in Jordan and the potential future e-waste will be estimated.

3.2. Issues Relating to E-waste Estimation in Developing Countries

Perez-Belis et al. (2015) conducted an in-depth literature review on e-waste management research. The authors observed that one of the major concerns of the literature was alarming e-waste growth due to accelerated technological advances and high obsolescence and rapid EEE consumption rates. E-waste generation was, therefore, one of the main issues

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[4] The results of this chapter were originally published in: Ikhlayel, M. 2016. Differences of methods to estimate generation of waste electrical and electronic equipment for developing countries: Jordan as a case study. Resources, Conservation and Recycling, 108, 134-139.

researched in the literature. The authors concluded there was a lack of standardized methods for their estimation.

In this chapter, Jordan's data was used to compare different estimation methods. With respect to the MENA region, in which Jordan is located, very few analysis assessment were available (Seitz, 2014). Except two countries, Morocco, and Tunisia, no complete national inventory assessment exists in the developing MENA countries. The scarcity of available data, experience, and technical support made it difficult to conduct an inventory assessment in many MENA countries and Jordan. For instance, Fraige et al. (2012) conducted a questionnaire and interviews to estimate the total e-waste amount generated in Jordan, but the generation of the secondhand products was not an interest of their study. The EEE examined included TVs, mobile phones, PCs, refrigerators, washing machines, air conditioners, microwaves, electronic games, and other EEE categories, such as printers, scanners, toys, etc. Their study revealed that Jordan produced 23,400 tons of e-waste from these EEE in 2010 from the household sector. However, the mathematical formula used in the study was not explained, and the results cannot be justified or compared with other studies.

3.3. Review of Methods of E-waste Estimation

Many studies were conducted to estimate e-waste generation in developed and developing countries. Several peer-reviewed studies that applied to developing countries were reviewed to understand (1) the reason for each method selection, (2) the appliances that were selected for e-waste estimation and (3) the methods of data collection. In the following sections, five estimation methods and their advantages and disadvantages and the required data for each method are discussed.

3.3.1. Model A: Consumption and Use Method

The Consumption and Use (referred to as "C&U" in this study) method was employed in the Netherlands to estimate the e-waste amount (Widmer et al., 2005). The C&U method (Eq. (3-1), it has also been referred to as "Approximation 1"). The C&U method is described in Crowe and Elser (2003), EEA (2003), Widmer et al. (2005), UNEP (2007), Schluep et al. (2012), Lau et al. (2013), and Li et al. (2015). Many studies applied the method in developing countries. Some studies refer to the method as "batch leaching (stock & lifespan)" (e.g., Polak and Drapalova (2012) and Gurauskiene and Stasiskiene (2011)), while other studies such as Mandhani et al. (1992) referred to the method as ''approximation'', ''estimate formula'' or also ''batch leaching''. The method was also called "Leaching Model" by van der Voet et al. (2002). In those of the reviewed papers, the method is also referred to as a "Leaching Model".

Required data are stock data in the current evaluation year and average lifespan. Stock quantities can be calculated by multiplying the number of households by the penetration rate of EEE per household. The penetration rate for the C&U method is defined as the percentage of households that owns, at least, one EEE, and its maximum value is one. Dividing the stock by the average lifespan gives the e-waste amount generated (in tons) in an evaluation year t. The method's formula is presented in Eq. (3-1).

$$WEEE_W(t) = \frac{H(t)\ N_h(t)\ W}{L} \tag{3-1}$$

Here, $H(t)$ is the number of households, $N_h(t)$ is the penetration rate of EEE per household, W is the average EEE weight and, L is the average lifespan. Suffix w denotes the weight of e-wasted by weight in ton.

This method might be useful in countries where data are scarce, or no inventory assessment of e-waste exists. In such cases, the method can provide a rough estimation of a minimal data requirement. Many studies applied the method in the context of developing countries. Examples of such studies are presented in Table 3-1. In the recent literature, the method was applied by Araújo et al. (2012a) in Brazil by using national statistical data to estimate e-waste from saturated market products: refrigerators, washing machines, TVs, freezers, and audio systems. The reason for the method selection seems to be its applicability for saturated products. The authors applied both the C&U and the Time Step methods for saturated and dynamic markets; whereas, in a dynamic market, technology is changing rapidly and demand for products is growing faster than in a saturated one.

Table 3-1. Examples of studies that applied the C&U method in developing countries

Study	Type	EEE	Geographical location
Laissaou and Rochat (2008)	National assessment report	Televisions, computers, and mobile phones	Morocco
Gurauskiene and Stasiskiene (2011)	Peer-reviewed paper	Refrigerators, freezers, washing machines, dishwashers, electric cookers, microwaves ovens, vacuum cleaners, electric irons, personal computers, mobile phones, TVs, video recorders/players, and video/photo cameras	Lithuania
Chung et al. (2011)	Peer-reviewed paper	Non-plasma and non-liquid crystal displays televisions, refrigerators, washing machines, air conditioners, and personal computers	Hong Kong
Araújo et al. (2012a)	Peer-reviewed paper	Refrigerators, washing machines, televisions, freezers, and audio systems	Brazil
Alavi et al. (2015)	Peer-reviewed paper	Refrigerators, freezers, televisions, washing machines, dishwashers, audio systems, air conditioners, desktop computers, monitors, laptop computers, mobile phones, telephones, and lamps	Iran

3.3.2. Model B: Time Step Method

The Time Step method estimates e-waste based on sales and stock data. The change of stock is the difference between the stock in the current evaluation year and the previous year. Potential e-waste represented by Eq. (3-2), e-waste equals sales minus the difference between stock inflow and outflow where *S(t)* is the sales, and *St(t)* is the current stock quantities in a year t. This method provides good results for a fully saturated market in which it treats EEE with a maximum penetration rate as in steady state conditions. The required stock data can be obtained from national statistics. Sales data can be obtained from Eq. (3-3).

$$WEEE(t) = S(t) - \{St(t) - St(t-1)\} \tag{3-2}$$

$$S(t) = I(t) + P(t) - E(t) \tag{3-3}$$

Where *I(t)* is the import quantities, *P(t)* is the production quantities, and *E(t)* is the export quantities at evaluation year t.

The method was, for example, used by Araújo et al. (2012a) to estimate potential e-waste from mobile phones and personal computers. The reason for the method selection seemed to be its applicability for a dynamic market, and the data used were gathered from national statistics.

3.3.3. Model C: Simple Delay Method

With the Simple Delay method, the e-waste generation in a year t is equal to historical sales data in a *t-L* year. The Simple Delay method can be used in a fully saturated market or products where the population is stable, and it can not capture the sudden change in technology in which a new-generation product replaces an EEE. The method's advantage is that the calculation can be carried out easily where the required data range is simple. Sales data can be obtained from import, production, and export of EEE (Eq. (3-3)). The method is presented in Eq. (3-4).

$$WEEE(t) = S(t-L) \tag{3-4}$$

The method was applied by Jain and Sareen (2006) and referred to as the Market Supply method to estimate the theoretical amount of e-waste in India for TVs and personal computers where data were obtained from the industry association. According to the authors, the Simple Delay method was selected for their study because it can be easily applied to e-waste estimation in the Indian context; and by considering constraints in data collection. There is another delay method by Tasaki et al. (2004) that is not simple, and it uses the distribution of lifespan of products. However, such a method requires data to estimate the distribution of lifespan and such data acquisition is difficult for developing countries.

3.3.4. Model D: Mass Balance Method

The Mass Balance method is similar to the Simple Delay method. It estimates e-waste generation by considering a number of sales, reused and stored EEE. The advantage of applying the method is that it examines different EEE paths (considering the number of sales, number of reused and the number of stored), and it requires assumptions. Mathematically, the method is represented by Eq. (3-5) where $S(t-L)$ is the sold quantities $R(t-L_r)$ is the reused quantity $Sr(t-L_s)$ is the stored quantity, L_r is the average lifespan of reused items, and L_s is the average stored EEE lifespan. Compared to other methods, more information about the fate of an EEE is required. However, such information about the quantities of reused and stored EEE can be obtained from a survey on consumer behavior. The method can be used for both saturated and dynamic markets, and its main advantage is it considers the material flow of e-waste. The method is presented in Eq. (3-5).

$$WEEE\ (t) = S(t-L) + R(t-L_r) + Sr(t-L_s) \tag{3-5}$$

3.3.5. Model E: Approximation 2 Method

With the Approximation 2 method, the estimation of e-waste is on the basis of sales data on the current evaluation year. The method requires sales data only for the assessment year, assuming a fully saturated market condition. The assumption of the method is that an EEE reaches the EoL with a sale of a new item. It can be applied in a fast-growing market for products with short lifespans (e.g. mobile phones). The main advantage of the method is to carry out a basic and initial inventory assessment. This method is rarely used in literature, and it was cited in some technical reports such as UNEP (2007). The method was coined in literature as Approximation 2, and its formula is presented in Eq. (3-6).

$$WEEE(t) = S(t) \tag{3-6}$$

3.3.6. Summary of Comparison Between the Methods

A comparison between different estimation methods was conducted to help select the most appropriate method to estimate e-waste from all EEE types or a particular EEE. Depending on data availability, the saturation level of each EEE and market conditions (e.g. saturated or dynamic), an appropriate estimation method can be different. Required data of the methods are presented in Table 3-2.

Table 3-2. Comparison between inventory methods

Estimation Method	Required data					Key references
	lifespan	Sales		Stock		
		M[4]	S	M	S	
C&U	✓				✓	van der Voet et al. (2002),Wang et al. (2013)
Simple Delay	✓		✓			Crowe and Elser (2003), UNEP (2007), Araújo et al. (2012b), Schluep et al. (2012), Lau et al. (2013)
Time Step			✓	✓		Crowe and Elser (2003), UNEP (2007), Araújo et al. (2012b), Lau et al. (2013), Wang et al. (2013)
Mass Balance[5]	✓	✓			✓	Matthews et al. (1997), Crowe and Elser (2003), UNEP (2007), UNEP (2009), Lau et al. (2013)
Approximation	✓		✓			Crowe and Elser (2003), Widmer et al. (2005), UNEP (2007), Araújo et al. (2012b), Schluep et al. (2012), Lau et al. (2013)

[4] “M” means “multiple” and that data in multiple years, current and past years, are required. “S” means “single” and that data in a single evaluation year is sufficient for calculation.

[5] Requires data on consumer behavior (sold, reused, and stored).

3.4. Estimation of E-waste Generation in Jordan

3.4.1. Procedure

The main aim of the estimations here is to compare the results obtained from the different methods and to estimate the current e-waste generation in Jordan as required for Chapter 5. The methods were compared based on the total e-waste produced from all appliances by applying each method, and the e-waste generated from each appliance individually.

Before the comparison, as the C&U method underestimates e-waste generation, it was modified to resolve its drawback. The method was paid attention because it has frequently been used in developing countries due to low data availability. The method was modified as follows.

1. Two parameters were changed, and e-waste generation was estimated without considering the secondhand market (hereinafter, referred to as "modified method 1").
2. Different parameters for secondhand products to the method 1 (referred to as "modified method 2") were introduced.

Then the study carried out the following two steps:

3. The estimates of the e-waste estimation methods are compared to understand advantages and disadvantages of each method, their required data, and under which assumptions and market conditions each method can be applied.
4. For estimating the future amount of e-waste, the modified method of the C&U (method 1) was applied as an application for utilizing the method. For this purpose, the average number of appliances owned by a person was estimated through a linear regression analysis. The modified method 1 was used for the future e-waste prediction because it considers the possibility that every person or household may own more than one individual appliance as it calculates the stocks in a different approach. Besides that, it considers future population. Due to difficulties of acquiring stock data in developing countries, stock amounts are commonly calculated in the literature on a household basis. For both current and future e-waste estimation, the calculations performed by multiplying the number of households by

the penetration rate per household, might not figure out the e-waste's amounts accurately. With the modified methods, the calculation of stock has to be performed by multiplying the population by the average number of an appliance that owned by a single user. Therefore, the calculations in the modified methods allow estimating the stock in use per person rather per household.

3.4.2. Modification of the C&U Method

3.4.2.1. Parameters

To address the C&U method's drawback for its down estimation of e-waste, its parameters were modified, and it was used in the study for potential e-waste estimation in Jordan. The modified method 1 is represented by Eq. (3-7) where $Np(t)$ is the number of EEE owned by a person, which comprises a value lesser or greater than one. Multiplying the population by the penetration rate per person gives the yearly stock in use; and penetration rate data can be calculated by conducting a survey.

$$WEEE_w(t) = \frac{P(t)\ Np(t)\ W}{L} \tag{3-7}$$

To include secondhand products in the estimation, further modifications to the method were applied by introducing multiple parameters. Eq. (3-8) was applied to estimate e-waste of TVs, refrigerators, washing machines, and mobile phones.

$$WEEE_w(t) = P(t)\ W\ Np(t)\left[\left(\frac{\omega}{L_n} + \frac{1-\omega}{L_o}\right)\right] \tag{3-8}$$

Here, $Np(t)$ is the average number of EEE owned by a person, ω is the market share of a new EEE item, $1\text{-}\omega$ is the market share of an old (secondhand) EEE item, L_n is the average lifespan of a new EEE item, and L_o is the average lifespan of an old EEE item. It was important to distinguish between personal computers and the other EEE items. For personal computers, the amounts of waste laptops and waste desktops were calculated from Eq. (3-9).

$$WEEE_w(t) = P\ (t)\ Np`(t)\ \left[W_d\left[\frac{\alpha}{L_{nd}} + \frac{\beta}{L_{od}}\right] + W_l\left[\frac{\gamma}{L_{nl}} + \frac{\delta}{L_{ol}}\right]\right] \tag{3-9}$$

Here, $Np`(t)$ is the average number of PCs (both laptop and desktop computers) owned by a person, α is the market share of new desktop computers, $\beta,$ is the market share of old desktop computers, γ is the market share of new laptop computers, δ is the market share of old laptop computers, L_{nd}, is the average lifespan of new desktop computers, L_{od} the is average lifespan of old desktop computers, L_{nl}, is the average lifespan of new laptop computers, L_{ol}, is the average lifespan of old laptop computers, W_d is the average weight of desktop computers, and W_l is the average weight of laptop computers.

The parameters, ω, α, β, γ, and δ can be calculated from sales data as the percentage of new EEE to total old and new EEE from Eqs. ((3-10)-(3-14)).

$$\omega = \frac{Sales\ of\ new\ EEE}{Sales\ of\ new\ EEE + Sales\ of\ old\ EEE} \tag{3-10}$$

$$\alpha = \frac{Sales\ of\ new\ desktop}{Sales\ of\ new\ PC + Sales\ of\ old\ PC} \tag{3-11}$$

$$\beta = \frac{Sales\ of\ old\ desktop}{Sales\ of\ new\ PC + Sales\ of\ old\ PC} \tag{3-12}$$

$$\gamma = \frac{Sales\ of\ new\ laptop}{Sales\ of\ new\ PC + Sales\ of\ old\ PC} \tag{3-13}$$

$$\delta = \frac{Sales\ of old\ laptop}{Sales\ of\ new\ PC + Sales\ of\ old\ PC} \tag{3-14}$$

It should be remarked that sales of old products can include both imported secondhand EEE and EEE reused domestically or either of them. Eqs. (3-10) - (3-14), sales for an old EEE or an old PC can be summed up to include both domestic and imported EEE, or it can be used as a parameter for either of them individually.

The modified methods (1 and 2) assume that an EEE will be replaced with new products once it reaches its EoL. The modified methods addressed the C&U method’s drawback in which it underestimates e-waste generation. The modified methods considered the population change, and the possibility that a single person may own more than one EEE (saturated or unsaturated). In the modified method 2, the introduced parameters allowed to include secondhand products in the estimations as they represent a significant portion in developing countries. The modified method 2 distinguished between desktop and laptop computers and these were treated in different ways as both have different weights and lifespans. Both the modified methods can be used for both saturated and dynamic markets.

3.4.2.2. Data Used

For all the seven methods including the modified ones, historical data on the number of households, an average number of people per household, current and future population, and the penetration rate of the selected EEE per household were obtained from JDoS (2015). The chosen EEE was mobile phones, laptops and desktop computers, TVs, washing machines, and refrigerators. They were selected because they represent the highest percentage of Jordan's e-waste stream. The import, production, and export data were extracted from the Harmonized Commodity Description and Coding System of each EEE from the online data of JDoS and UN Comtrade (2015). The study used Fraige et al. (2012) survey results for the average lifespan and the calculation of the penetration rate per person. The author obtained the data on secondhand EEE through a visit to Jordan's ministry of environment in August 2015. The data provided covered all the country's imported secondhand EEE from 2011 till 2013. The lifespan of an old product was assumed half of the new one. See Appendix A-E for the data used as parameters for the estimation methods.

3.5. Results and Discussion

Most of the estimation methods provide similar results regarding the total e-waste amount generated but different estimations for each EEE. The divergence occurs because the total amount of e-waste produced by applying each method depends on the market condition. The selection of a suitable method has to consider the market situation of each appliance.

A method might be appropriate for a specific appliance while another is not. Therefore, some methods estimate, for example, refrigerators' e-waste differently.

For fully saturated EEE, such as refrigerators, washing machines, and TVs, the original C&U method can be used for estimation of those products. The method can be used under the condition that each household owns, at least, a shared EEE by the household members. With unsaturated EEE such as mobile phones, the method cannot be used as it significantly underestimates the amount of e-waste generated. That is because more than one mobile phone exists in a single household where the average household size is usually high in developing countries. The Simple Delay method was also not suitable due to the fast-growing rates of mobile phones in fast-growing markets. However, the Simple Delay method provides good results for a fully saturated EEE. The Time Step and the Mass Balance methods provided very similar results for unsaturated EEE. That can be attributed to the fact that these items are growing fast in a growing market and within a relatively short lifespan and because of a quick change in technology (e.g. mobile phones and PCs). Both methods can also be applied to saturated and unsaturated EEE as they provide similar results compared with other methods. With the Approximation 2 method, the method overestimates the amount of e-waste compared to the other methods. That can be attributed to the fact that the method assumes an EEE reaches its EoL with the sale of a new product which is not applicable to Jordan's case. However, its applicability is for a fully saturated market. In such a case, the method applies for an appliance with a short lifespan. That occurs when an old product is replaced by the sales of a new one. Table 3-3 shows the results obtained from each estimation method. For all appliances, the average value of e-waste amounts from a particular appliance produced by comparing all methods was calculated. Then the e-waste production was divided by the mean value. The quantities of WEEE generated from each EEE and by applying each method is presented in Figure 3-1.

Table 3-3. Comparison of estimates of e-waste generated quantities
(Calculated from different estimation methods)

Method	M	L	D	TV	R	WM	Total	Per capita (kg/person/year)
C&U	0.2	1.2	0.3	0.7	0.9	0.8	4.1	3.0
Time Step	1.4	0.8	0.9	0.9	0.7	1.1	5.8	3.3
Simple Delay	0.8	0.8	1.1	0.8	0.8	0.7	5.0	3.0
Mass Balance	1.4	0.8	1.0	1.3	0.7	1.3	6.5	3.7
Approximation 2	1.5	1.0	1.1	1.1	1.5	1.3	7.5	4.8
Modified method 1	1.2	0.9	1.2	1.1	1.1	0.9	6.4	3.8
Modified method 2	1.2	1.5	1.4	1.1	1.1	0.9	7.2	4.0

M: mobile; L: Laptop; D: Desktop; R: Refrigerator; WM: Washing machine.

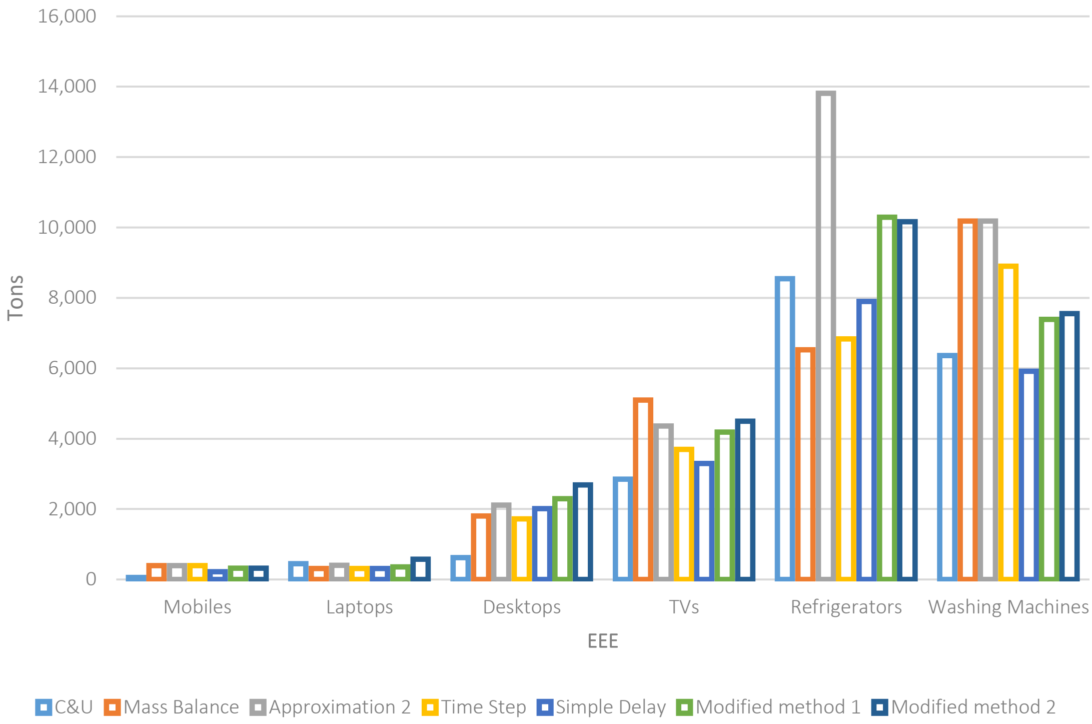

Figure 3-1. E-waste generation quantities from different estimation methods

The results from the modified method 2 showed that the annual e-waste generated from refrigerators, washing machines, TVs, desktop and laptop computers, and mobile phones are 10,430 tons, 7,500 tons, 4,500 tons, 2,700 tons, 570 tons, and 320 tons, respectively. These estimations included firsthand and secondhand products in 2013. The total amount of e-waste generation by applying the modified method 2 was found around 26,000 tons, which represented 3.8 kg/person/year. For all methods, the per capita rate varied between 3.0 and 4.8 kg/person/year. Since the MENA region is an unbalanced region regarding economic development, the per capita rate of e-waste generation in Jordan differs from other countries in the region, and it falls below the MENA's region average. The results of future e-waste generation from both firsthand and secondhand EEE are presented in Table 3-4 by using 2013 as a baseline year and by applied the modified method 2.

Comparing the e-waste generated to the total MSW gives an insight into the significance of e-waste generated. It was found that Jordan's e-waste represents 1.24% of the MSW generation. By applying the modified method 1, the study estimated that Jordan would produce around 43,000 tons of e-waste in 2030. Figure 3-2 shows the predicted amounts of Jordan’s e-waste. The future market share of the secondhand products was not projected in this work. Therefore, the modified method 1 was used for future e-waste prediction because the modified method 2 requires data on future secondhand products.

Table 3-4. E-waste generation in Jordan from firsthand and secondhand EEE in ton

EEE	Firsthand	Secondhand	% of firsthand	% of secondhand	Total
Mobile phones	324	0	100	0	324
Laptop computers	510	61	98	2	571
Desktop computers	2,275	413	85	15	2,688
PCs (laptops and desktops)	2,785	475	85	15	3,260
TVs	3,876	624	86	14	4,500
Washing machines	7,220	336	96	4	7,556
Refrigerators	10,161	267	97	3	10,428

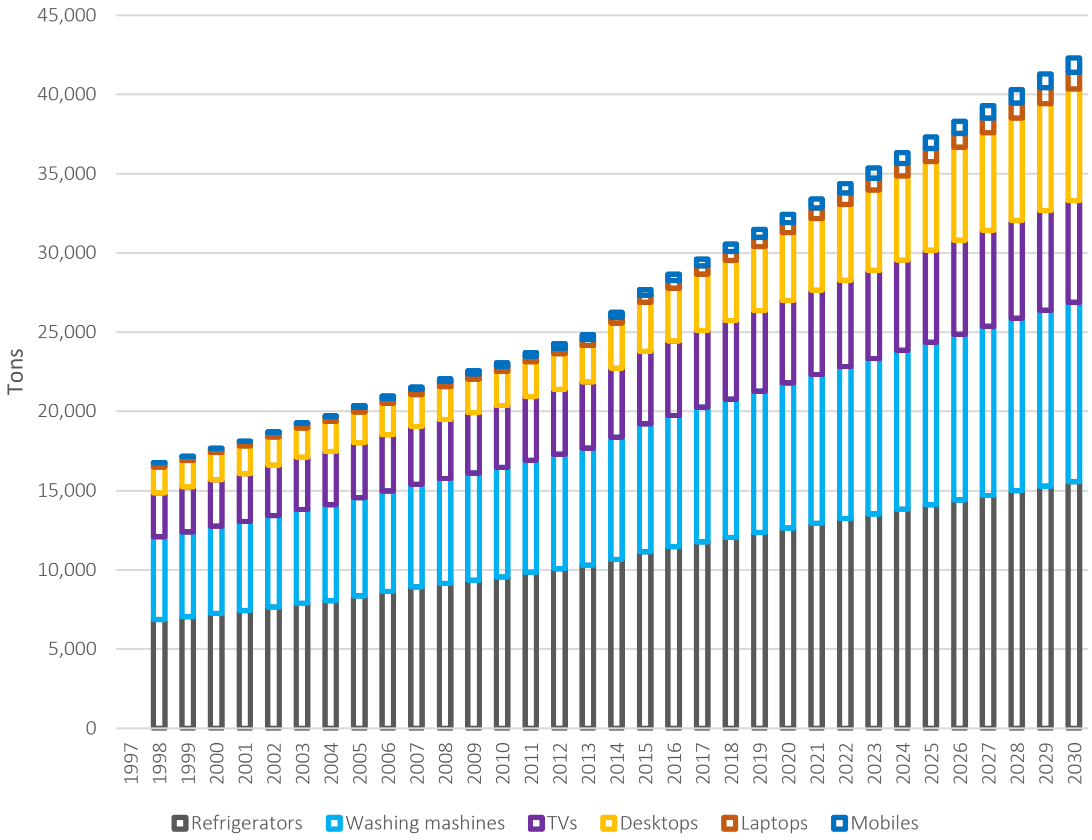

Figure 3-2. E-waste generation and extrapolation in Jordan
(Results obtained from the modified C&U method 1)

3.6. Conclusion of Chapter 3

In this chapter, the pros and cons of five most common e-waste estimation methods used for developing countries and frequently cited in literature were compared by using Jordan's data. It can be concluded from the results that the estimation methods must be applied cautiously, depending on the market conditions (e.g., saturated or developing). The C&U method, which had been mainly used for developing countries because data is limited, is suitable where data is scarce and to build a basic e-waste estimation. However, it provides good results for saturated appliances under the condition that the penetration rate is close to one. The underestimation of e-waste amounts is the major disadvantage of the method. The modified methods address the C&U's drawback by following a different approach that depends on the penetration rate per person rather than per household. The modified methods 1 and 2 consider the change in population. They also estimate both firsthand and secondhand products. Both consider the stock in use per person rather than per household. Because of data restriction, a common disadvantage of all the examined methods is that they use the average lifespan instead of its distribution. The results concluded that for a proper selection of e-waste method, the market conditions for each EEE must be taken into account.

Because the IEWM approach proposed in Chapter 2 requires a precise estimation of e-waste generated, it was necessary to determine an appropriate method for assessment of IEWM in developing countries. Based on the results obtained in chapter 3, the modified method 2 was selected to be used for evaluation of environmental impact of e-waste management in Chapter 5.

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4. ENVIRONMENTAL AND ECONOMIC EVALUATION OF MUNICIPAL SOLID WASTE MANAGEMENT[5]

4.1. Aim of this Chapter

This chapter seeks to estimate and evaluate the environmental impacts of the current MSWM practices and alternative improvement technologies. This evaluation is needed for achieving an IEWM system that was proposed in Chapter 2. The IEWM is grounded on the fact that MSW is mixed with e-waste, and both the waste management systems share waste treatment and disposal technologies. In another word, the IEWM utilizes the existing infrastructure of MSW systems to treat both MSW and e-waste streams. Since such infrastructure exists for MSW treatment, the IEWM suggests evaluating these facilities for its ability to deal with MSW streams in an environmentally-friendly and economically-viable manner. The purpose of the suggested evaluation is to examine what option or options are suitable to the present situation of MSW management in developing countries.

The structure of this chapter is as follows. Section 4.1.1 describes the current MSWM situation in the case of Jordan. This was necessary to understand how waste is managed in the country and its capability to establish an environmentally-friendly and economically-viable solution to municipal waste management for developing countries. It was also necessary to examine the current practices for a proper design of alternative MSWM scenarios. Section 4.1.2 describes the present situation in Amman, the capital city and the focus of this chapter. Section 4.2 represent the methodology undertaken in this chapter. The results are shown in Section 4.3.

4.1.1. Current MSWM Situation in Jordan

Jordan, like many other developing countries, is facing a challenge of managing e-waste. E-waste in most of developing countries, including Jordan, is mixed with MSW (Osibanjo

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[5] The results of this chapter was originally published in: Ikhlayel, M., Higano, Y., Yabar, H. & Mizunoya, T. 2016. Introducing an Integrated Municipal Solid Waste Management System: Assessment in Jordan. Journal of Sustainable Development, 9, 43-53.

and Nnorom, 2007, UNDP, 2011, Dwivedy and Mittal, 2012, Ibrahim et al., 2013). Therefore, the MSWM situation in Jordan was reviewed, analyzed, and evaluated.

In all Jordan’s cities, landfills are the primary disposal method in the country’s waste management plan. Twenty landfill sites are available throughout the country, but only one sanitary landfill, the only and the biggest sanitary landfill is available, that receives waste from the capital city and nearby cities. Thirty-five percent of the MSW is treated at the sanitary landfill site in the capital city. Fifty percent of the waste generated in the entire country is placed in any of the 19 uncontrolled landfill sites, 8% is open dumped, and the remainder is unofficially recycled (SWEEP-NET, 2010). The current landfills are still causing environmental problems such as water contamination in groundwater and surface water resources. The landfill sites and their adverse impacts issue were thoroughly investigated in recent literature (Al-Jarrah and Abu Qdais, 2006, Abu Qdais, 2007a, Abu Qdais, 2007b, Aljaradin and Persson, 2010, Aljaradin and Persson, 2012a, and Aljaradin and Persson, 2013). The material flow of Jordan’s MSW is illustrated in Figure 4-1 in which the collection coverage is 70%, 90%, and 100% in rural, urban areas and Amman City respectively.

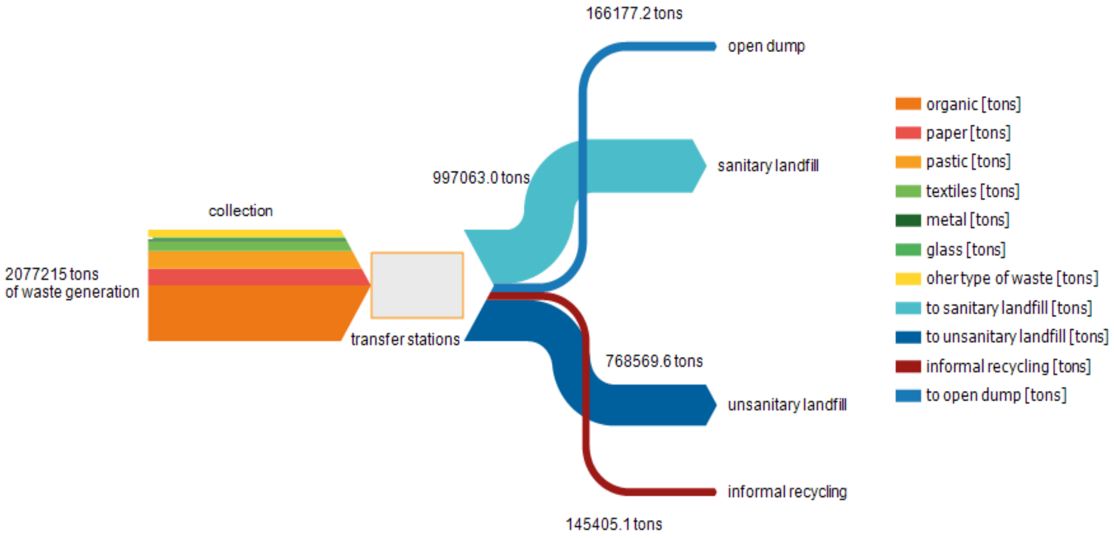

Figure 4-1. Material flows of the entire MSWM system in Jordan

4.1.2. Current Situation of MSWM in Amman City

The population of Amman City, the focus of this study, is 2.4 million comprises 38% of the entire country's population. The city's waste generation is seasonal because the country is a destination for individual and medical tourism. During summer, the city's population increases to 3 million (Alhyasat, 2012a) by a factor of 25%. The city is the backbone of the country's economy; about 50% of the country's employment opportunities are in the city, which comprises 80% of the country's economy (World Bank, 2004).

Amman City[6] generates 2,731 tons of waste per day (996,815 tons per year). Thirty-five percent of the waste produced in the entire country is deposited at the Al-Ghabawi[7] landfill site, the only sanitary landfill in the country. The groundwater and surface water contamination risk is unlikely to be significant due to the landfill's physical characteristics (World Bank, 2008a). However, this situation does not apply to the other landfills in the country (19 uncontrolled landfills). According to a phone interview in 2016 by the author with a waste management official in charge of the landfill site; the site receives negligible amounts of e-waste fractions. Therefore, this landfill site was excluded from the evaluation of e-waste management scenarios in Chapter 5 and it was included in the evaluation process in this chapter. The background information provided in Sections 4.1.1 and 4.1.2 was used to design different MSWM e-waste scenarios. That includes waste composition, collection, material flow of waste, the status of landfill sites, and potential generation of electricity from sanitary landfill sites and incineration. This situation was considered to evaluate the e-waste practices in Jordan in Chapter 5.

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[6] The city is divided into six operational zones and 27 districts. MSW is collected in 20,000 containers with the size of 1.1 m^3 Alhyasat, A.G. 2011a. *Municipal solid waste management finance and cost recovery in the City of Amman* [Online]. Regional Solid Waste Exchange of Information and Expertise Network (SWEEP-NET). Available: http://www.sweep-net.org/.

[7] This landfill was established based on international standards such as combined landfill gas and leachate collection, also meets the World Health Organization (WHO) standards MoEn. 2009. *Jordan Environmental Assessment report* [Online]. Jordan Ministry of Environment. Available: http://www.moenv.gov.jo [Accessed June 19, 2012]. The Al-Ghabawi site was established with the help of the World Bank and registered as a Carbon Development Mechanism (CDM) project (100,000-150,000 t-CO_2 per annum).

4.2. Methods

4.2.1. Overall Procedure

The below steps were followed to achieve the aim of this chapter:

1. The future amount of MSW was predicted by calculation based on future population and per capita rate of MSW generation. These calculations were performed to estimate the potential future amounts that can be disposed in the landfill sites when designing landfill-based scenarios. On the contrary of e-waste, data on waste characterization and generation was available, and therefore, the characterization of the waste stream and the MSWM generation was not estimated in this chapter. The data are described in Section 4.2.6.
2. Ten MSWM scenarios were designed based on specific criteria.
3. LCA was performed to estimate the current emissions from the present situation and to evaluate alternative and advanced options regarding environmental impacts.
4. A weighted score of the environmental impacts was calculated and specified to each environmentally evaluated scenario.
5. Cost analysis was conducted to estimate the cost of each alternative option for managing MSW.

4.2.2. MSW Forecasting

MSWM requires accurate estimation of solid waste generation (Dyson and Chang, 2005). The future amount of MSW was calculated by multiplying population in the future and the waste generation per capita (Eq. (4-1)).

$$W(n) = \frac{[365 \times P(n) \times P_c\ (n)\ ]}{1000} \tag{4-1}$$

Where *W(n)* is the amount of waste in n year in the future (ton), *P(n)* is the population in n year obtained from JDoS (2015), $P_c\ (n)$ is waste generation per capita in n year (kg/person/day).

The current waste generation per capita rate is 0.9 kg/person/day. According to the World Bank, the waste generation per capita in the country will reach 1.3 kg/person/day in 2025 (Hoornweg and Bhada-Tata, 2012). From Eq. (4-1), the waste amount will reach 4 million tons by the year of 2025.

4.2.3. Scenarios of MSWM for Jordan

The scenarios were designed based on these criteria:

i. The concept of the IWM was applied to all scenarios in which what-if analysis was applied to answer the question "what happens if…". For instance, what will happen to the overall environmental performance of an individual scenario if informal recycling is replaced by formal recycling or unsanitary landfill is superseded by sanitary landfill, or if incineration is combined with sanitary landfill, etc. The IWM concept was applied in the way that it sees the integration of several technologies for waste handling and disposal for a waste management system.

ii. Introducing scenarios that improve the current situation gradually.

iii. The percentages for each waste process were parameters to examine the overall performance of an individual scenario. For example, the percentages of waste processes in the Scenario S2-D are 28% formal recycling with separation (the rate of the maximum theoretical recycling), and 72% sanitary landfill with energy recovery (the remaining waste). The percentages here were applied as parameters to examine the influence of each treatment and disposal option on the overall performance. The rate of the maximum theoretical recycling was estimated as follows: the total amounts of dry recyclable amounts (paper cardboard, plastic, glass, and metals) divided by the total amount of MSW generated in the entire country, and by assuming 30% of materials and metals lost as residues at MRFs. The assumption of the 30% was assumed as in the IWM model developed by

McDougall et al. (2001). The material loss is mainly due to the mixed nature of the MSW stream.

The designed scenarios are explained as below:

- S0: the baseline scenario that represents the current waste management in the entire country, where approximately 85% of the waste stream is landfilled. In this scenario, the waste composition was considered as 52% organic, 16% film and dense plastic, 20% paper and cardboard, 2% glass, 2% ferrous and non-ferrous metals, and 8% textiles (World Bank, 2008b). The same waste composition was considered in the all other scenarios.
- S1: in this scenario, the current MSWM was improved by introducing waste separation to the baseline scenario; Scenario S0) through an MRF. The recycling rate was two times the current ratio (14%). The purpose was to investigate how much proper recycling can improve the current waste management system, both environmentally and economically.
- S2-A: MSW is fully treated in sanitary landfills.
- S2-B: it is similar to Scenario S2-A with the exception that, the recycling rate was increased from 7% to 14%.

The other scenarios present different waste management alternative technologies that attempt to eliminate or to reduce further the environmental problems resulting from the improper waste management and are explained below:

- S2-C: is the same as the S2-B with the exception that energy is recovered from sanitary landfills.
- S2-D: the recycling rate was increased to 28%, and waste is sanitary landfilled with energy recovery from the sanitary landfills (the maximum theoretical recycling rate).
- S3-A, S3-B, and S3-C: the recycling rate was increased from 7% to 14%. The major change is that 10% of the waste is composted and biogasified for Scenarios S3-A

and S3-B respectively, where Scenario S3-C considers both composting and biogasification.

- S4: incineration technology was introduced by incinerating 50% of the waste and energy was recovered and 80% of ferrous metal removed from bottom ash.

All the scenarios consider 100% of waste collection coverage. The recycling rate represents the recycling percentage of dry recyclable waste in materials (paper and cardboard, plastic, metals, and glass) while the ratio of composting and biogasification represents the percentage of composting and biogasification from the organic waste stream. In Scenarios S2-C and S2-D, gas collection efficiency in the landfill sites was 75%, the theoretical and maximum gas gathering rate and energy is recovered as electricity only.

The assumption of the 75% for gas collection efficiency from the sanitary landfill was assumed based on the WRATE software (the academic version (v3)). As the WRATE software suggests, the efficiency cannot be greater than 75% unless the landfill site has a very high level of engineering. For incineration, the gross electrical efficiency is considered as 30% (the maximum efficiency is usually 30% if energy is recovered as electricity only, while 90% if energy is recovered as electricity and steam ((McDougall et al., 2001)). Table 4-1 shows the ten scenarios for MSW treatment.

Table 4-1. The assessed 10 scenarios of MSWM

Scenario number	Recycling		Landfill			Composting	Biogasification	Incineration	Source of energy recovery
	Informal	Formal	Open dump	Sanitary	Unsanitary				
S0	7%		8%	35%	50%				
S1		14%		43%	43%				
S2-A		7%		93%					
S2-B		14%		86%					
S2-C		14%		86%					Landfill
S2-D		28%		72%					Landfill
S3-A		14%		76%		10%			
S3-B		14%		76%			10%		
S3-C		14%		66%		10%	10%		
S4		28%		22%				50%	Inc.

4.2.4. Life Cycle Assessment

The method of LCA was employed to estimate the environmental impacts of each proposed MSW scenario. Standard steps were taken in the LCA procedure: goal and scope definition, inventory analysis, and impact assessment. In the step of goal and scope definition, the system boundary and the purpose of this study were determined: to assess the environmental impacts of the current MSWM system and other alternative scenarios. The scope of LCA in this study includes seven processes: collection, composting, biogasification, incineration, recycling, and landfilling. The system boundaries were defined as gate-to-grave of the EoL phase from different proposed scenarios for an assumed 20-year lifespan. Geographically, the boundaries included MSW collection and treatment in the entire country.

The CML 2001 (Centrum voor Milieuwetenschappen Leiden (Guinée and Jeroen, 2002)) method of the Life Cycle Impact (LCIA) was applied to evaluate the 10 scenarios by applying six LCIA impact categories: resources depletion (abiotic resources), acidification potential, eutrophication potential, freshwater aquatic ecotoxicity, GWP, and human toxicity potential. Weighting Factors (WFs) by thinkstep 2012, global survey results described by Baitz et al. (2014) were applied to each scenario. The procedure of the LCA calculation followed characterization, classification, normalization, and weighting; and it can be expressed as in Eq. (4-2). Then, a weighted score was assigned for each scenario, and it was calculated from Eq. (4-3) from a scale of 0 to 100 in which the lower the weighted score, the best the overall environmental performance.

$$w_i = \sum_{i=1,j=1}^{i=0,j=p} \left(s_i . p_{ij} . c_{jk} . n_k . w_{f.}\right) \tag{4-2}$$

Where:

w_i: weighted impacts

p_{ij}: emissions of pollutant j from a load of waste i

s_i: a load of waste i

c_{jk}: characterization factor for pollutant j to impact category k

n_k: normalized factor for category k

w_f: weighting factor for impact category k

$$ws = \frac{wi_e - wi_{min}}{wi_{max} - wi_{min}} \tag{4-3}$$

Here:

wi_e: is the weighted score for the presently evaluated scenario

wi_{min}: the minim weighted score among all the evaluated scenarios

wi_{max}: the maximum weighted score among all the evaluated scenarios

The “weighted score” refers to a score that assigned to each scenario’s weighted environmental impacts. In which the environmental impacts are weighted by using WFs. The scaled scores from 0 to 100 values the overall environmental performance for the chosen LCIA impact categories in which the lower the score, the better the performance. That is because the lower the score indicates lower environmental impacts and higher benefits.

4.2.5. Cost Analysis

Data of expenditure cost (Alhyasat, 2011b), materials and metals prices (Aljaradin et al., 2011), and the cost of treatment of 1 ton of waste for various technologies (World Bank, 2008b) were collected. The total cost was calculated from Eq. (4-4) and the cost recovery was calculated from Eq. (4-5). Table 4-2 shows the extracted data from Alhyasat (2012b) in which it was used for comparing the alternative scenarios with the present situation. Figure 4-2 demonstrates the cost of treatment of 1 ton of waste as obtained from the study by World Bank (2008b).

Table 4-2. The current waste management cost with and without charge in Amman City (Data extracted from Alhyasat (2012b))

	Without tariff system			With tariff system		
MSWM Category	Cost/ton (USD)	Net cost (Million USD)	% of total cost	Cost/ton (USD)	Net cost (Million USD)	% of total cost
Collection	35.8	32.6	79.8%	21.7	19.7	79.8%
Transfer	4.9	4.5	11.0%	3.0	2.7	11.0%
Disposal (landfilling)	4.1	3.7	9.1%	2.5	2.2	9.1%
Total	44.8	40.8	-	27.1	24.7	-

$$\text{Net cost} = \text{Expenditure cost} - \text{Revenues} \tag{4-4}$$

$$R_r = \frac{\sum_p W.R}{\sum_p W.C} \tag{4-5}$$

Here, p is a waste process, R_r is the recovery ratio for each scenario, W is waste treated or disposed, C is the cost of treatment of 1 ton of waste, and R is revenue from 1 ton of waste.

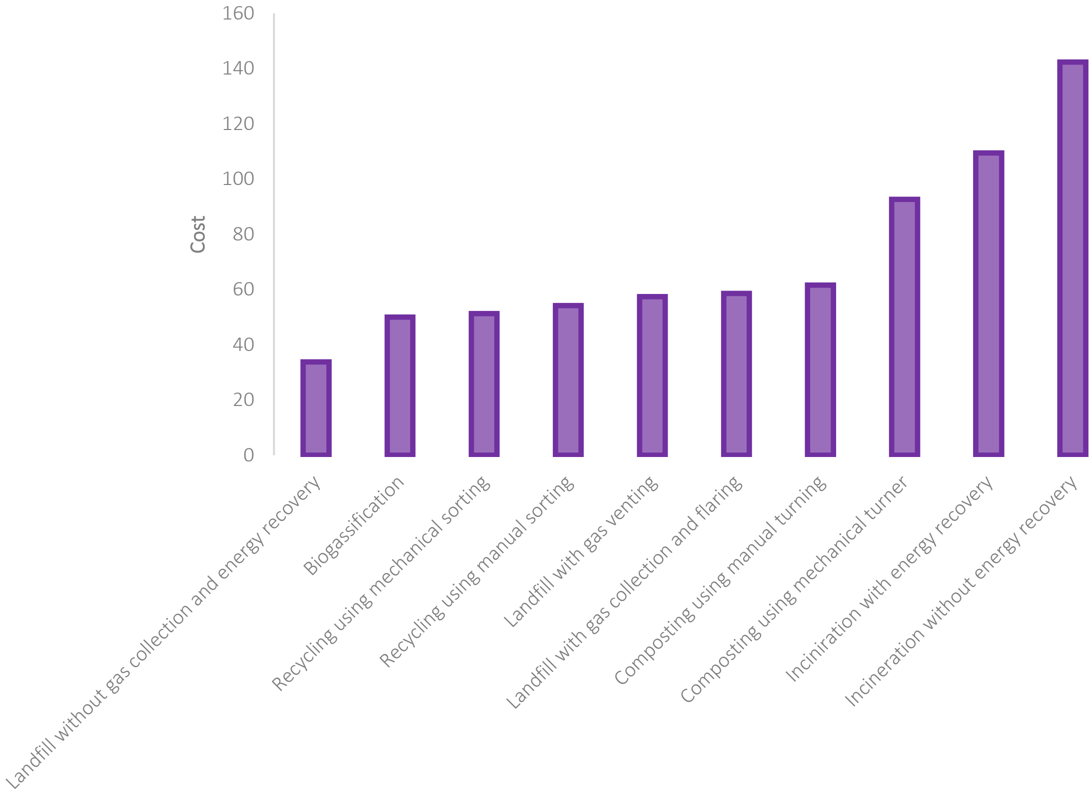

Figure 4-2. Cost of treating 1 ton of waste
(Currency: USD). World Bank (2008b)

4.2.6. Data Used

The foreground data and information were gathered for each scenario input from different sources, including official agencies (e.g. Ministry of Environment, Amman Greater Municipality, and officials from eight municipalities were interviewed by e-mail communication through the embassy of Jordan in Tokyo), international organizations such as the World Bank and Japan International Cooperation Agency, regional organizations such as the Regional Solid Waste Exchange of Information and Expertise Network in Mashreq and Maghreb Countries (SWEEP-NET), the Arab Environment Forum, and literature addressing the waste management problem including: Abu Qdais (2007a), Abu Qdais (2007b), Aljaradin and Persson (2010), Aljaradin and Persson (2012b), and Aljaradin and Persson (2012a). The background data for LCA inventories was used from the ecoinvent 3.1 database.

4.3. Results and Discussion

4.3.1. Results of Pollution Estimation from the Baseline Scenario

The pollution emitted from the current MSWM system was estimated. The major pollutants of both to air and water were estimated as shown in Tables 4-3 and Table 4-4 for the current baseline scenario (S0), that represents the current MSWM situation. CO_2 and CH_4 are mainly emitted from collection and landfill sites, and part of the pollution could be avoided through recycling. CH_4, NOx, and CO were emitted during waste collection and landfilling. Landfill processes mainly caused the other pollutants to air and water. Emissions were compared with the country's national GHG inventory in Section 4.3.3.

Table 4-3. Air emission from waste management system in the S0 baseline scenario in ton

	Waste management processes			Total
	Collection	Landfill	Recycling	
GHG	258,72	211,0142	-869,82	204,9032
CO_2	252,27	570,190	-864,00	509,017
CH_4	31	733,27	-49	733,10
NOx	454	582	-382	654
Total HC	0	384	0	384
CO	138	305	-272	171
H_2S	0	37	0	37
HCl	0	19	-3	16

Table 4-4. Water emission from waste management system in the S0 baseline scenario in ton

	Waste management processes			Total
	Collection	Landfill	Recycling	
Chloride	205	358	562	1,125
Biochemical Oxygen Demand (BOD)	0	381	64	445
Sulphate	7	129	262	398
Total Organic Carbon (TOC)	0	2	118	120
Suspended Solids	22	33	64	119
Nitrate	0	0	34	34
Iron	0	30	-2	28

4.3.2. Materials Recycled in the Scenarios

The amounts of actually recycled materials for each scenario were estimated. They were 58,160 tons in Scenarios S0 and S2-A. They were116,325 tons in Scenarios S1, S2-B, S2-C, S3-A, S3-B, and S3-C. They were 232,650 tons in Scenarios S2-D and S4. The results showed that the maximum dry recyclable waste (from paper, cardboard, plastic, metals, and glass) was approximately 763,400 tons. However, only 534,390 tons of this amount can be practically recycled after assuming complete separation at an MRF (without kerbside sorting) and 30% material loss. Thus, the percentages of recycling in the scenarios are 7%, 14%, and 28% represent 10%, 21.76% and 43.5% respectively of the maximum and theoretical recycling amounts (534,390 tons). The results also showed that the materials recycled could be increased by 33.5% if waste separation is applied at the source.

4.3.3. Greenhouse Gas Emissions

Net GHG emissions estimated in the S0 (the baseline scenario) were 2,035,500 tons per year. According to the inventory data published by UNFCC (2010), The country's GHG emissions were estimated as 20.14 million tons-CO_2/year. Comparing the estimation in this study to the inventory, it was found that the country's GHG emissions from solid waste accounted for 10% of the entire country's emissions since 2010. It was also found that the GHG emission reduced from solid waste by 25% through establishing the sanitary landfill site (the landfill is without energy recovery) in 2003 in Amman City. Scenarios S1, S2-A, S2-B, S2-C, S3-A, S3-B, S3-C, S4 and S2-D reduce GHG emissions by 28%, 44%, 47%, 48%, 50%, 51%, 54%, 74%, and 80% respectively (considering the assumptions in Section 4.2.3). Figure 4-3 shows the calculated GHG emissions for all scenarios. See appendices F-K for the examined environmental impacts of each scenario and each waste management process expressed in Kg-equivalent. It must be mentioned that the collection system was assumed the same for all the proposed scenarios.

Figure 4-3. GHG emissions in each scenario

4.3.4. *Results of Evaluation of the Scenarios*

The results for evaluating each scenario are shown in Figure 4-4. Each scenario was evaluated by applying the CML 2001 impact assessment method where a weighted score was assigned to each scenario (the smaller the score, the better the performance). Scenario

S2-D achieved the highest environmental performance, mainly because of replacing the unsanitary by sanitary landfills with energy recovery from landfills and implementing the highest recycling rate. Scenario S4 was the second best scenario were incineration technology was introduced with energy recovery. In this scenario, it was assumed 20% is the gross efficiency of electricity generation where energy is recovered as electricity only. The third best environmental performance was obtained through biological treatment technologies (composting or biogasification or both; see Scenarios S3-A, S3-B, and S3-C). However, their scores were very similar to scenarios S2-C and S2-B.

Figure 4-4. Weighted scores of the environmental impacts of the evaluated scenarios

Slagstad and Brattebo (2013) performed an uncertainty analysis on a modified waste composition. The findings of their study showed that the waste composition is necessary for the total environmental impacts of a waste management system, especially for the global warming, nutrient enrichment, and human toxicity via water impact categories. The authors stated that if the quantities of source-separated material are known the uncertainty is low. The authors concluded that availability of good data on the amount of waste recycled, and the quality of importance for the reliability of the results. In developing countries, the report by Hoornweg and Bhada-Tata (2012) showed similarities for waste composition in developing countries for low-income, lower-middle-income, and middle-income countries. For instance, organic waste in low-income and lower-middle-income countries are 64% and 59%, and 54% in middle-income countries. For the case of developing countries, organic waste accounts for 28%. For recyclable materials such as paper, plastic, and metals, a similar situation exists in developing countries. Therefore, this study assumed a similar waste composition exists in developing countries, especially in MENA countries.

4.4. Results of Cost Analysis

Data extracted from Alhyasat (2012b) showed a detailed analysis of the current MSWM cost in Amman City. The collection cost accounted for 79.8% of the total cost, 35.8 USD/ton. The total cost per the weight of waste was 44.8 USD/ton with a cost recovery estimated at 60.6% in Amman City. The cost recovery for the entire country was calculated as 50.5%). The part of the cost of MSWM collection is currently recovered through a tariff system in the. The total revenues, total cost and the recovery cost for each alternative scenario with and without the tariff system are presented in Table 4-5. According to SWEEP-NET (2013), the charge for waste management was applied to the electricity bill with a flat rate of 28 USD/household and a proportional fee of 0.007 USD/kWh for electricity consumption when the monthly consumption of electricity is greater than 200 kWh/month. The alternative scenarios improve the overall cost through revenues. For the best scenario regarding environmental impacts, S2-D, the cost recovery without a tariff system was 95.4% and almost economically feasible. The tariff system is unlikely to be abolished, and with the current tariff system, the cost recovery was approximately 150%, showing its economic feasibility. Alternative scenarios that were not economically feasible were scenarios S2-A, S3-C, and S4.

Table 4-5. Results of cost analysis for each alternative scenario

Scenarios	Revenues (million USD)				Total revenues (Million USD)	Net cost (Million USD) (with inclusion of the tariff system)	Recovery ratio with tariff system (%)	Recovery ratio without tariff system (%)
	Biological treatment	Thermal treatment	Landfill	Sorting and recycling				
S0	0	0	0	0	0	24.7	61.1	44.8
S1	0	0	0	27.1	27.1	25.3	107.1	49.8
S2-A	0	0	0	10.1	10.1	20.5	49.3	22.0
S2-B	0	0	0	26.8	26.8	25.0	107.1	51.1
S2-C	0	0	3.3	33.7	33.7	25.3	120.2	59.8
S2-D	0	0	6.6	53.9	53.9	34.7	155.5	95.4
S3-A	47.3	0	0	27.1	79.0	63.7	116.8	83.4
S3-B	56.8	0	0	27.1	83.9	41.9	200.2	124
S3-C	54.7	0	0	27.1	160.3	85.9	95.2	73.4
S4	0	11.5	0	32.4	65.4	159.7	41.0	22.1

4.5. Conclusion of Chapter 4

As proposed by the IEWM approach, this chapter attempted to estimate the environmental loads of the current and alternative MSW treatment and disposal options by using Jordan as a case study for developing countries; mainly for the MENA region. The environmental loads from landfill, recycling, composting, biogasification, and incineration were estimated. Nine MSW scenarios were proposed by following the IWM approach and evaluated by employing the LCA method. The scenarios were evaluated environmentally and economically. The results showed that the best scenario is the scenario that implements sanitary landfilling, recycling, and waste-to-energy with waste separation. The economic cost of each alternative was estimated and compared with the present situation. The results indicated that the scenario that included 28% of dry recyclable materials through MRF and sanitary landfills with energy recovery of the remainder reduced GHG emissions by 80%, and it provided the best environmental and economic performance (the recovery cost more than 100% and economically feasible). The results also showed the scenarios that feature composting or biogasification or both could provide a notable improvement of the environmental impacts, and they should be paid attention when considering the cost and revenues. The results revealed that the recycled amounts could be increased by 33.5% if the waste separation was practiced at the source of generation. The results obtained from this chapters will be employed in Chapter 4 for achieving and IEWM system.

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5. ENVIRONMENTAL EVALUATION OF PRESENT PRACTICES AND ADVANCED TECHNOLOGIES FOR IEWM SYSTEMS

5.1. Aim of this Chapter

This chapter seeks to evaluate the environmental impacts of the improper e-waste handling practices and advanced treatment technologies, based on the IEWM approach proposed in Chapter 2. Three advanced management options of state-of-the-art treatment technologies -sanitary landfilling, proper recycling of metals, materials, and precious metals, and incineration of PCBs and plastic- were compared with the present practices. Six primary e-waste products were targeted for the assessment, and the results of e-waste generation estimated in Chapter 3 were used. Results from Chapter 4 were employed to set scenarios of IEWM systems that are combined with MSWM systems. The scenarios of IEWM were evaluated environmentally and economically to find the most environmentally-friendly and economically feasible options. The cost and revenues of e-waste were assumed to have no notable influence on the overall cost of an IEWM system for the systems that include e-waste scenarios. The rationale of this assumption is that the ratio of e-waste to MSWM is 1.24% (calculated from Chapter 3). The recycling rate of e-waste are 10%, and the recycling efficiency is 80%. This assumption was due to restrictions on data availability of cost and revenues of e-waste.

5.2. Method

5.2.1. Overall Procedure

The overall procedure of the evaluation is as below:

1. Waste management scenarios were designed by applying the IWM concept in which various technologies were utilized in combinations. Two types of the scenarios were prepared as below:
    i. Ten MSWM scenarios as discussed in Chapter 3. The scenarios featured sanitary landfill, recycling, composting, biogasification, and incineration

in which energy is recovered from biogasification, incineration, and landfill.

   ii. Seven e-waste management scenarios including six EEE products: mobile phones, laptop computers, CRT TVs, LCD TVs, washing machines and refrigerators. (Section 5.2.2).

2. LCA method was used to evaluate combinations of the ten MSWM and the seven e-waste management scenarios (70 cases) using data and results from Chapters 3 and 4. (Section 5.2.3).
3. WFs by thinkstep 2012, global survey results ((Baitz et al., 2014)) were used to weight different environmental impacts of each scenario. A weighted score was calculated for each scenario on a scale from 0 to 100 in which the lower the score, the better the environmental performance.
4. The scores of the ten MSWM and the seven e-waste scenarios were summed up and compared. The weighted scores were summed up after summing up the impacts of both MSWM and e-waste scenarios.

Overall, four types of data were used: economic data in which it was used to evaluate the cost, foreground data for e-waste inventory was required for comparing the e-waste estimation methods and for Jordan’s e-waste estimation, background data in which it was used for the LCA calculations, and foreground data needed for evaluating the systems (data that describes the entire system). The background data was for LCA calculations, and it was necessary to estimate the environmental impacts of each waste process for the evaluated scenarios. The detailed data used were described in Section 5.3.

5.2.2. The Proposed E-waste Management Scenarios

The e-waste scenarios for LCA were designed as shown in Table 5-1. They attempt to ameliorate the present improper practices gradually and examine the existing state-of-the-art technologies with a comparison with the present inadequate e-waste practices in the developing countries. The evaluated scenarios are described as below.

- The baseline scenario (E0) is the scenario that represents the current e-waste management practices in Jordan in which the e-waste is handled inappropriately through informal recycling by 10%. The reminder of waste is landfilled in the country's unsanitary landfills after a specific period (82%), and open dump sites (8%). There are no authorized figures on the amounts of waste recycled; it was assumed, based on a discussion with waste management experts in Jordan in August 2014 and August 2015, that the informal recycling rate is 10% in the baseline scenario. For the other scenarios, it was assumed that 10% of e-waste is formally recycled.
- Scenario E1 assumes prohibiting open burning and replacing it with formal recycling in the current situation and in which unsanitary landfills and open dumps are still practiced.
- Scenario E2 consider sanitary landfill of the complete waste.
- Scenario E3 considers replacing unsanitary landfill and open dump sites with sanitary landfills and formal recycling.
- Scenarios E4, E5, and E6, included state-of–the–art technologies: material recycling (non-thermal, and thermal with energy recovery), and incineration of PCBs with energy recovery. Incineration is combined with energy recovery for both incineration of plastic and PCBs.

Table 5-1 shows the scenarios for the six selected EEE. The assumptions undertook in the study and the data used for scenario assessment are explained in Table 5-2. The inventory analysis for all scenarios was performed with LCI data described in Section 5.3. Emissions to air, water, and soil were estimated from the baseline scenario and the alternative scenarios from the waste treatment and disposal methods.

Table 5-1. The scenarios for e-waste treatment

Scenarios	Unsanitary landfill	Open dump	Open burning	Sanitary landfill	Metals recycling	Precious metals recycling	Incineration of Plastic	Incineration of PCBs scrap
E0	✓	✓	✓					
E1	✓	✓			✓			
E2				✓				
E3				✓	✓			
E4				✓	✓	✓		
E5				✓	✓	✓	✓	
E6				✓	✓	✓	✓	✓

Note: Glass is disposed in sanitary landfills in all scenarios.

5.2.3. Life Cycle Assessment

LCA method was employed to assess and evaluate the environmental impacts of the present improper e-waste management systems and state-of-the-art technologies

Two approaches can be followed to perform an LCA calculations. The first is the sequential approach (also known as the “bottom-up approach”) based on a simplified linear of input and output for a scenario through the EoL stage of a waste management system. The sequential approach is frequently used, and it can be found in software programs such those software models based on Microsoft Excel sheets (Klöpffer and Grahl, 2014). The complete calculations that followed in this chapter are based on the sequential approach (as implemented by GaBi ts software). Fundamentally, the computation of an impact category indicator equals the summation of a flow quantity multiplied by the characterization factor per flow quantity. The mathematical expression is shown in Eq. (5-1) in which it considers characterization, classification, normalization, and weighting. The other approach is based on matrix inversion as described by Heijungs et al. (2012), and the sequential approach is discussed by Baumann and Tillman (2004). Detailed and standard LCA steps undertaken in this chapter are discussed in Section 5.2.3.1 through Section 5.2.3.4.

5.2.3.1. System Boundaries

Three waste management processes were taken into account for the baseline scenario of e-waste: open burning, open dump, and unsanitary (uncontrolled) landfill. In regards to the alternative scenarios of IEWM systems, the following processes were considered: sanitary landfill, metals recycling, thermal recycling of materials, and incineration of plastic and PCBs. The system boundaries for evaluating the MSWM scenarios included collection, sanitary landfilling, recycling, composting, biogasification, and incineration of the MSWM’s waste streams (as seen in Chapter 4). The LCA assessment was conducted for the entire waste streams at a national level.

5.2.3.2. Functional Unit

The functional unit is 23,111 ton of six e-waste products handled in the entire country, which was calculated in Chapter 3. The following EEE products were considered: mobile phones, laptop computers, TVs, washing machines, and refrigerators discarded from the households. The products were chosen because the penetration rates of these selected appliances at households range from 97.5% to 98.9% while it is less than 50% of other appliances (Fraige et al., 2012).

5.2.3.3. Inventory Analysis

The inventory analysis was performed with LCI data described in Section 5.3. The environmental loads of resource in use and pollutant emissions (emissions to air, water, and soil) of the scenarios in relation to the defined functional unit in this study were calculated.

5.2.3.4. Life Cycle Impact Assessment

The Milieuwetenschappen Leiden (CML; (Guinée and Jeroen, 2002))[8] was used to calculate the environmental impact categories. The categories are resources depletion

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[8] The CML 2001 method is a problem-oriented LCIA method. It was selected among existing methods for the purpose of this study because their environmental impacts categories consider emissions from waste. In the case of e-waste, the method was applied in literature for both EEE and their generated waste either by looking at the entire life cycle or the EoL phase. Case studies that employed the CML method include Sole, M., Watson, J., Puig, R. & Fullana-i-Palmer, P. 2012. Proposal of a new model to improve the collection of small WEEE: a pilot project for the recovery and recycling of toys. *Waste Manag Res,* 30**,** 1208-12, Bhakar, V., Agur, A., Digalwar, A.K. & Sangwan, K.S. 2015. Life Cycle Assessment of CRT, LCD and LED Monitors. *Procedia CIRP,* 29**,** 432-437, Xiao, R.F., Zhang, Y., Liu, X. & Yuan, Z.W. 2015. A life-cycle assessment of household refrigerators in China. *Journal of Cleaner Production,* 95**,** 301-310, Xue, M., Kendall, A., Xu, Z. & Schoenung, J.M. 2015. Waste management of printed wiring boards: a life cycle assessment of the metals recycling chain from liberation through refining. *Environ Sci Technol,* 49**,** 940-7.. These example studies employed the CML method for evaluating MSWM related research: den Boer, J., den Boer, E. & Jager, J. 2007. LCA-IWM: a decision support tool for sustainability assessment of waste management systems. *Waste Manag,* 27**,** 1032-45, Martinez-Blanco, J., Colon, J., Gabarrell, X., Font, X., Sanchez, A., Artola, A. & Rieradevall, J. 2010. The use of life cycle assessment for the comparison of biowaste composting at home and full scale. Ibid.30**,** 983-94, Pikon, K. & Gaska, K. 2010. Greenhouse Gas Emission Mitigation Relevant to Changes in Municipal Solid Waste Management System. *Journal of the Air & Waste Management Association,* 60**,** 782-788, Giugliano, M., Cernuschi, S., Grosso, M. & Rigamonti, L. 2011. Material and energy recovery in integrated waste management systems. An evaluation based on life

(abiotic resources) depletion, acidification potential, eutrophication potential, freshwater aquatic ecotoxicity, GWP, and human toxicity potential. The WFs by thinkstep 2012 - global survey results described by Baitz et al. (2014) - were used to weight the environmental impacts. The LCA calculation procedure is expressed in Eq. (5-1). To evaluate the seven scenarios using the CML 2001 method into a single weighted score for each scenario; a weighted score for each scenario was calculated from Eq. (5-2) and assigned to each scenario. The weighted scores of the ten MSWM and all scenarios of e-waste were summed after summing up the weighted impacts of the MSWM and e-waste scenarios. Ther weighted scores were compared to determine the most environmentally effective IEWM scenario.

$$w_i = \sum_{i=1,j=1}^{i=0,j=p} \left(s_i . p_{ij} . c_{jk} . n_k . w_f\right) \tag{5-1}$$

Where:

w_i: weighted impacts

p_{ij}: emissions of pollutant j from a load of waste i

s_i: a load of waste i

c_{jk}: characterization factor for pollutant j to impact category k

n_k: normalized factor for category k

w_f: weighting factor for impact category k

$$ws = \frac{wi_e - wi_{min}}{wi_{max} - wi_{min}} \tag{5-2}$$

Here:

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cycle assessment. *Waste Manag,* 31**,** 2092-101, Grosso, M., Nava, C., Testori, R., Rigamonti, L. & Vigano, F. 2012. The implementation of anaerobic digestion of food waste in a highly populated urban area: an LCA evaluation. *Waste Manag Res,* 30**,** 78-87, Kaazke, J., Meneses, M., Wilke, B.M. & Rotter, V.S. 2013. Environmental evaluation of waste treatment scenarios for the towns Khanty-Mansiysk and Surgut, Russia. *Waste Management & Research,* 31**,** 315-326, Burnley, S., Coleman, T. & Peirce, A. 2015. Factors influencing the life cycle burdens of the recovery of energy from residual municipal waste. *Waste Manag,* 39**,** 295-304..

wi_e: is the weighted score for the presently evaluated scenario

wi_{min}: the minim weighted score among all the evaluated scenarios

wi_{max}: the maximum weighted score among all the evaluated scenarios

5.3. Data Used

Several background and foreground data for each e-waste scenario were used. For the background data, LCI data provided by thinkstep (2016): the professional database and the EoL dataset were used. The ecoinvent database created by the ecoinvent center was used. The used version was the one provided by thinkstep (2016) for GaBi ts software version 7.2 (the integrated ecoinvent database; version 3.1). To obtain process inventory data for e-waste disposal in unsanitary landfills and open dumps, the model for waste-specific and climate-specific life cycle inventories of open dumps and unsanitary landfilling of waste described in Doka (2016a) was used. An appropriate e-waste composition was applied for suitable regional climate parameters were inserted in the model. The model's parameters were adjusted to obtain process inventories of the unsanitary landfill and open dump sites that applicable to the case study (see Table 5-2). Similarly, the model for waste-specific life cycle inventories of open burning of waste described in Doka (2016b) was used to get inventories of informal recycling of copper, aluminum, and iron.

For the foreground data on the country's material flow and informal recycling activities, it was collected by the author during field trips work in August 2014 and August 2015 to Amman and Irbid cities. The author conducted interviews with several waste management practitioners (four people), government officials (seven people) and two academic individuals involved in the waste management issues of the country and observed the current situation. The data on the substance composition of the studied appliances from the work done by Oguchi et al. (2013) was used. The data on the material composition of the selected appliances was used from the study conducted by Blaser and Schluep (2011). For the country's electricity mix and power losses, the data from Vagliasindi and Besant-Jones (2013) and NEPCO (2014) were used. The data and assumptions used in the study are explained in Table 5-2.

Table 5-2. Major data and assumptions used in Chapter 5

Parameter	Data used	Source of data
Percentage of informal recycling in the baseline Scenario (E0)	10%	Field trip in August 2014 and 2015
Density of air pollution releases from informal recycling	Low density (rural)	Assumption
Soil pollution release from informal recycling	To agricultural soil	Assumption
Mean values of the landfill characteristics	Jordan’s climate-specific data: precipitation: 484 mm/year, temperature: 20 C, annual actual evapotranspiration: 650 mm/year, landfill gas collection: 0, methane correction factor: 1 for unsanitary landfills and 0.5 for open dump sites	Abu Qdais (2007) and Abu Qdais et al. (2010), Doka (2016a), and Suleiman and Al-Bakri (2011)
Unsanitary landfill and open dump sites	The unsanitary, uncontrolled, conventional or traditional landfill is defined in this study as simply dumping waste, leveling, and compacting it to reduce the size. A daily and final soil cover are applied daily. Here, there is no lining is applied and no leachate collection and no biogas utilization. Open dumps represent	Field trip on August 2015 and Alfayez (2011)

	disposal sites in which waste is dumped in open areas without soil cover or any further treatment	
Mean value of percentage of recycling in other scenarios	10%	As the baseline scenario (Scenario E0)
Mean value of recycling efficiency	80%	SEPA (2011)
Energy required for recycling	308 kWh/ton for precious metals and 66kWh/ton for other metals	Bigum et al. (2012)
Energy mix	Jordan-specific data: heavy fuel: 42%, natural Gas: 8%, diesel: 50%	Vagliasindi and Besant-Jones (2013) and NEPCO (2014)
Power losses (electricity generation)	Jordan-specific data: generation losses: 5%, distribution losses: 2%	Vagliasindi and Besant-Jones (2013) and NEPCO (2014)
E-waste fractions from mobile phones, laptop computers, TVs, washing machines and refrigerators	1.2%, 2.2%, 17.3%, 29%, and 40% respectively.	Calculated from the modified method 2 in Chapter 2 (The market share of LCD TVs was estimated at 52% and the 48% of CRT TV based on sales data obtained from Jordan's department of statistics website (http://web.dos.gov.jo/?lang=en) and data of imported secondhand EEE from a visit to the ministry of environment in 2015 in Amman City).
Cost analysis of e-waste scenarios		The cost and revenues were compared with the results of cost estimations from Chapter 4. The ratio of e-waste to MSWM

	is 1.24% (calculated from Chapter 3) in which the cost and the recycling rate of e-waste are 10%, and the recycling efficiency is 80%. Therefore, the cost and revenues of e-waste were assumed to have no notable influence on the overall cost of the IEWM scenarios.

5.4. Results and Discussions

5.4.1. Emissions from Current E-waste Management

Emissions to air, water, and soil and the weighted environmental impacts from the improper practices (unsanitary landfill, open dump, and open burning) were calculated. The results of toxic emissions are shown in Table 5-3. It was found that all emissions from the baseline scenario of all pollutants contribute by 80.7 and 19.2% to air and soil respectively. Emissions from the current e-waste management system were mainly to air and soil (See Table 5-3

and “Appendix M” for the complete inventory of all emissions from the e-waste management scenarios and “Appendix L” for the MSWM scenarios). This due to the semi-arid to arid nature of Jordan’s climate. The agricultural land in which the fate of soil emissions is to the industrial and agricultural soil. In the case of Jordan and according to World Bank (2016), the agricultural land accounts for 11.9%.

Figure 5-1 shows an example of results obtained from different climate conditions for disposal of 1kg laptop waste in an unsanitary landfill site (without PCBs disposal). The two climate types are arid as is seen in Jordan and the other is humid. The main climate parameter for the humid climate are: mean annual precipitation: 1000 mm/year; mean annual temperature: 8 °C; mean annual actual evapotranspiration AET: 500 mm/year.

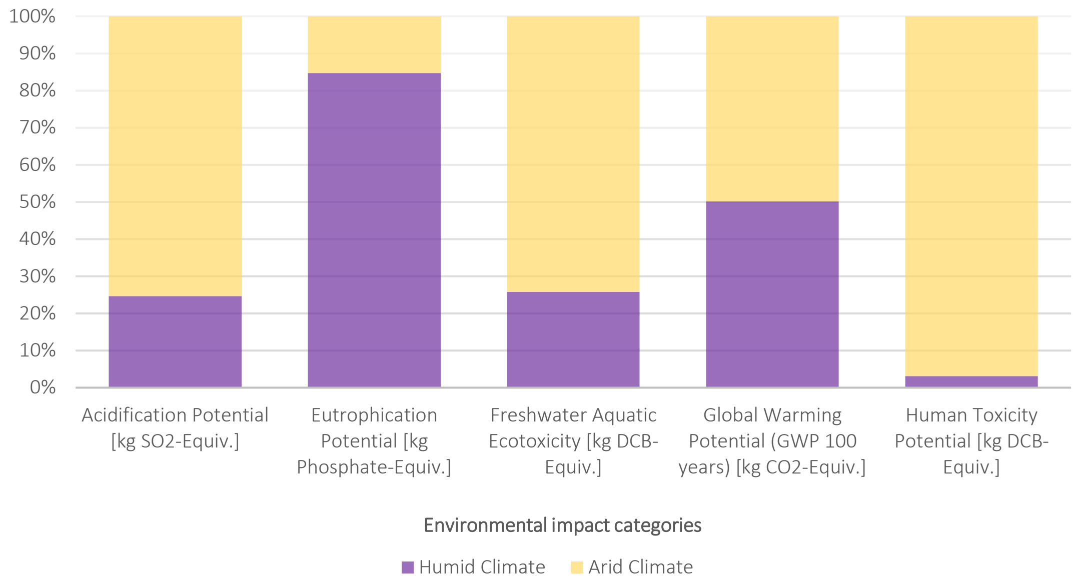

Figure 5-1. Environmental impacts of waste from a laptop computer - arid vs. humid climate conditions

The toxic pollutants in Table 5-3 were mainly relative and contributed to two impact categories: freshwater aquatic ecotoxicity and human toxicity potential as shown in Figure 5-2 and Figure 5-3. The major contributors to emissions are PCBs from unsanitary sites, open dump sites, and open burning respectively; and they contribute to 39.3% of the aggregate emissions. Environmental impacts of disposal of ferrous metals in the baseline scenario were significant where the best environmental performance was obtained from the disposal of aluminum. Emissions from toxic substances (lead, antinomy, chromium, cadmium, and mercury) are the major focus of this study and are shown in Table 5-3.

Table 5-3. Emissions from toxic substances estimated for each EEE from the baseline Scenario (E0)

Impact Category	Pollutant	CRTTV	Laptop	LCD TV	Mobile	Refrigerator	Washing Machine	Total (kg/ton)
2	Sb	1.4.E-1	1.5.E-1	1.3.E-1	4.0.E-1	6.0.E-2	2.0.E-1	1.1.E+00
1	Sb	1.1.E-2	9.9.E-3	9.7.E-3	2.2.E-2	4.3.E-3	1.1.E-2	6.8.E-2
3	Sb	8.8.E-2	8.8.E-2	7.7.E-2	2.2.E-1	3.3.E-2	1.1.E-1	6.2.E-1
2	As	7.0.E-4	1.1.E-3	7.0.E-4	2.4.E-3	1.0.E-4	4.0.E-4	5.4.E-3
1	As	6.6.E-4	9.9.E-4	6.5.E-4	2.6.E-3	1.1.E-4	3.3.E-4	5.4.E-3
3	As	6.6.E-3	8.8.E-3	5.5.E-3	2.5.E-2	9.9.E-4	3.3.E-3	5.0.E-2
2	Cd	3.9.E-3	4.0.E-3	2.9.E-3	9.0.E-3	1.0.E-3	5.0.E-3	2.6.E-2
1	Cd	3.0.E-3	3.3.E-3	3.0.E-3	8.7.E-3	1.1.E-3	4.4.E-3	2.4.E-2
3	Cd	2.9.E-2	2.2.E-2	2.9.E-2	7.7.E-2	1.1.E-2	3.3.E-2	2.0.E-1
2	Cd	3.0.E-2	3.3.E-2	1.2.E-2	7.5.E-2	2.0.E-3	2.0.E-3	1.5.E-1
1	Cd	2.2.E-6	1.1.E-6	2.2.E-6	4.4.E-6	1.1.E-6	4.4.E-6	1.5.E-5
1	Cd	8.9.E-5	8.9.E-5	5.3.E-5	2.3.E-4	6.4.E-6	4.0.E-6	4.7.E-4
3	Cd	7.7.E-4	8.5.E-4	4.0.E-4	2.3.E-3	5.5.E-5	4.4.E-5	4.4.E-3
2	Pb	1.2.E-1	5.0.E-1	2.0.E-1	7.1.E-1	6.0.E-2	2.0.E-2	1.6.E+00
1	Pb	1.2.E-1	3.3.E-1	2.1.E-1	6.7.E-1	5.6.E-2	2.2.E-2	1.4.E+00
3	Pb	1.2.E+00	3.3.E+00	2.0.E+00	5.5.E+00	5.4.E-01	2.2.E-01	1.3.E+01
2	Hg	5.0.E-5	9.0.E-5	5.0.E-5	2.2.E-4	7.0.E-6	2.0.E-5	4.4.E-4
1	Hg	9.6.E-5	1.2.E-4	8.5.E-5	3.2.E-4	3.2.E-5	8.5.E-5	7.3.E-4
3	Hg	5.5.E-4	8.8.E-4	5.5.E-4	2.7.E-3	1.1.E-4	4.4.E-4	5.3.E-3

“1” denotes emissions to air;“2” denotes “emissions to agricultural soil”; “3” denotes emissions to the industrial soil.

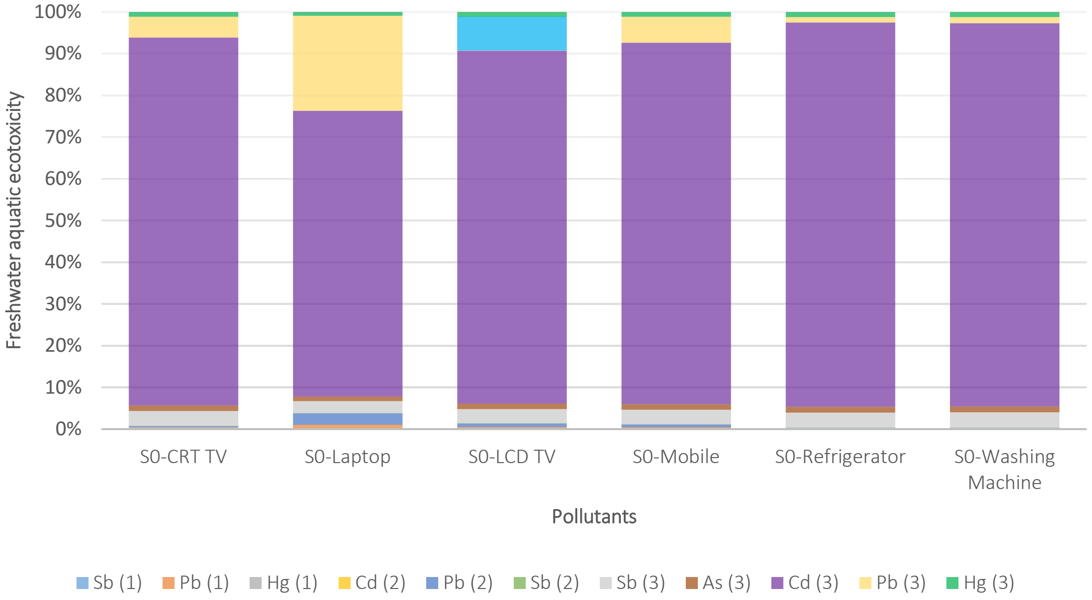

Figure 5-2. Relevant pollutants contribute to freshwater aquatic ecotoxicity (Scenario E0)
("1" denotes emissions to air; "2" denotes "emissions to agricultural soil"; "3" denotes emissions to the industrial soil)

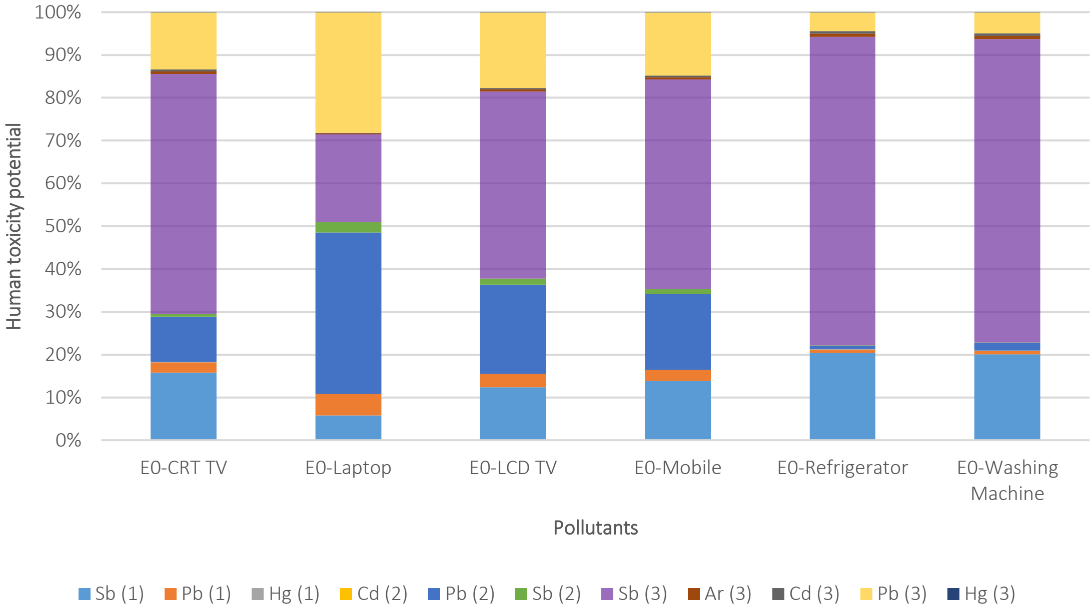

Figure 5-3. Relevant pollutants contribute to human toxicity potential (Scenario E0)

5.4.2. Environmental Evaluation of the IEWM Scenarios

It was found that the impacts of climate change were significant from the MSWM scenarios while they were low in the e-waste management scenarios. That is due to the high fraction of organic waste in which methane gas was released significantly. Carbon dioxide was also a contributor to MSWM scenarios due to waste collection and transportation of a much higher MSWM waste fraction compared to e-waste. In the case of the e-waste management scenarios, human toxicity was significant. It contributed to approximately 47.80% of the total examined impact categories in the baseline scenario (Scenario E0) while freshwater aquatic ecotoxicity contributed by 26.56%, and acidification potential contributed by 15.54%. These impact categories contributed by 89.90% of the total impacts (abiotic depletion was not estimated in the baseline scenario due data unavailability).

For developing countries, the impacts of human toxicity and acidification potentials, and freshwater aquatic ecotoxicity are much more relevant to the environmental situation of developing countries, and global warming is less significant. One reason, as it is a global issue rather than national or regional. Another reason is the contribution of global warming of the country is not large. For instance, it was calculated in Chapter 4 that the contribution of solid waste to the entire countries' emissions accounts for approximately 10%. According to Jordan ministry of the environment, Jordan is a mere contributor to the global GHG emissions with just a marginal emission rate of 0.01% of total worldwide emissions.

By comparing e-waste management scenarios to the MSWM scenarios, scenario S0 was the worst among all the scenarios followed by Scenario E0 (the present situation of e-waste management). Eutrophication potential is much more relevant to MSW and it caused by landfilling. Scenarios E1 and E2 (e-waste scenarios), they can importantly amend the waste management situation for an IEWM system for better overall performance. In Scenario E1, open burning was assumed prohibited and was superseded by formal recycling while in the E2 scenario, sanitary landfill with energy recovery was utilized. Scenario S2-D (MSWM scenario) was the most promising scenario among the examined MSWM scenarios while Scenario E6 (e-waste management scenario) was the most promising scenario for managing e-waste. Both were regarding the environmental impacts. With the MSWM scenarios, global warming and human toxicity potentials are the highest. Acidification and eutrophication potentials were noted in the current MSWM situation as well as freshwater aquatic ecotoxicity. For the present situation of e-waste handling, the significant impacts came from human and acidification potentials followed by climate change.

Figure 5-4 shows the environmental impacts of the present situations of MSWM (S0) versus e-waste (E0) scenarios by comparing the contribution of MSWM and e-waste to the total emissions (to an IEWM system and for the present waste management situation). The contribution of climate change and eutrophication potentials are negligible in Scenario E0 while climate change and eutrophication potentials were presented significantly in the MSWM system. Human toxicity potential in the MSWM scenario was also high. The freshwater aquatic potential is more significant in an e-waste scenario. It can be observed that the environmental impacts of e-waste are significant when compared to MSWM; the leading contributor is human toxicity. It should be remarked that the results presented here (and other results in this chapter) are based on 10% of e-waste are informally recycled, 82% are disposed in unsanitary landfills and the reminder to open dump sites. This is not necessarily happening annually; rather these percentages show the fate of e-waste after a specific time. These results, therefore, assume that the amount of reduced EEE and stored will reach the final destination after an unknown period. This assumption is due to lack of knowledge of the material flow of e-waste in many developing countries and including Jordan. For example, there are no figures on the stored amounts of EEE. Thus, these results consider all of the e-products when they are believed to be entirely disposed.

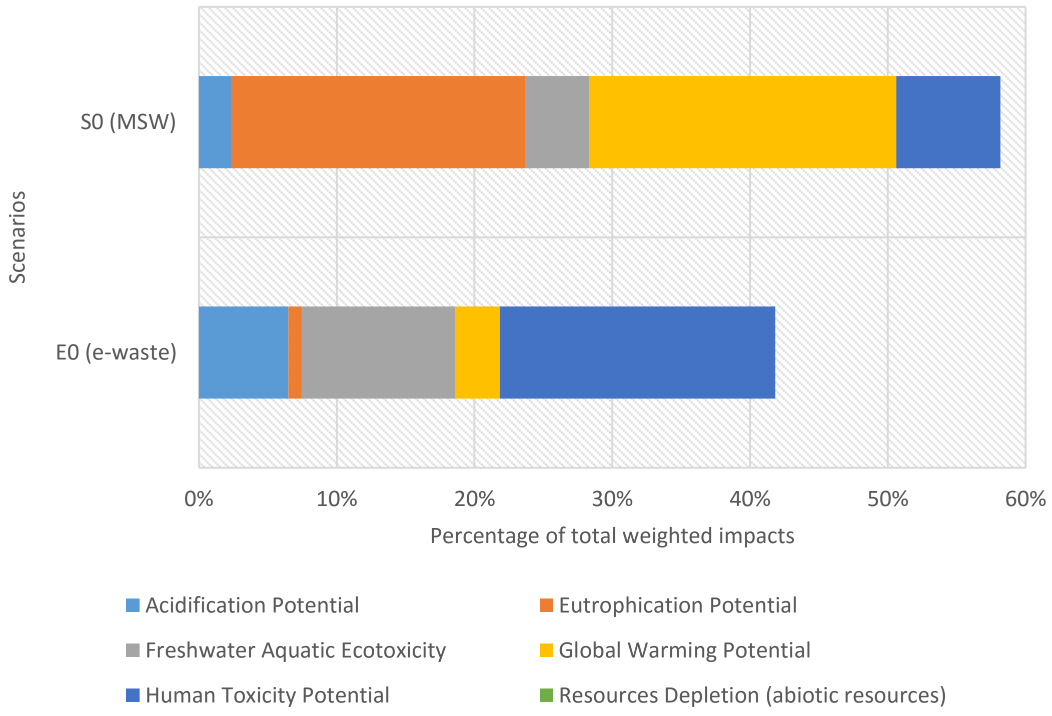

Figure 5-4. Contribution of Environmental impacts of MSWM and e-waste scenarios

The weighted environmental impacts of the seven e-waste management scenarios including impacts and benefits from each e-waste management for each EEE and from the six environmental impact categories are shown in Figure 5-5. A relative and weighted score was calculated for each scenario and based on a scale from 0 to 100 in which 0 is the optimal situation, and 100 is the worst situation as the higher the weight, the higher the negative impacts. The results obtained from Eqs. (5-1) and (5-2), in which the weighted environmental impacts were calculated from Eq. (5-1) and the weighted score of the environmental impacts from Eq. (5-2). The results were as the follows: 100, 61, 18, 16, 2.1, 1.8, and 0 for Scenarios E0, E1, E2, E3, E4, E5, and E6 respectively. Incineration of PCBs seems to be a more beneficial option compared to sanitary landfill. Nevertheless, the performance of both technologies is similar. Improving the current situation (the baseline; Scenario E0) by replacing open dump and unsanitary landfills by sanitary landfills and prohibiting open burning can significantly improve the situation (Scenario E3) in which the performance was evaluated at 18. However, another improvement option is the introduction of a recycling scheme of metals to the current situation. The performance was evaluated at 61 for such an option (Scenario E1). Introducing precious metals to the recycling scheme can notably improve the overall performance in which the performance of a recycling scheme without precious metal is 16 and 2.1 with precious metals recycling (Scenario E4).

Although Scenario E6 provided the best environmental performance regarding both the impacts and the benefits of all appliances (mobile phone, laptop, CRT TV, LCD TV, washing machine and refrigerator), the environmental performance for treatment and disposal of each appliance in the compared scenarios differs. Therefore, the choice for a proper e-waste management scheme should take the e-waste characterization and composition into account for proper selection of e-waste management technologies for a specific city or country. For instance, the best environmental performance was obtained from these scenarios: E4-Mobile, E6-Mobile, E5-Mobile, E4-LCD TV, E6-LCD TV, E5-LCD TV, E4-CRT TV, E6-CRT TV, E5-CRT TV, E6-Laptop, E4-Laptop, and E5-Laptop. That is due to the high levels of precious metals concentration. Therefore, appliances that contain a high content of precious metals can provide best environmental performance if scenarios E6 or E5, or E4 are applied. That is because the environmental benefits of the precious metal recycling (e.g., gold, palladium, and silver) including the avoided burdens from the same virgin metals have higher benefits. Less concentration of precious metals content provided the worst environmental impacts for each of the seven scenarios. For example, refrigerators and washing machines. Therefore, the quantities, weight, and waste materials and metals composition of each EEE are key factors for the environmental performance of each EEE individually and each scenario. The weighted environmental impacts of all the scenarios are shown in Figure 5-5, and the weighted score for treatment and disposal of each EEE are shown in Figure 5-6. The environmental impact categories were calculated for each scenario expressed equivalent units are listed in Table 5-4. It can be seen that the environmental impacts from the baseline scenario, Scenario E0, the worst and significant especially when compared from the impacts from other scenarios.

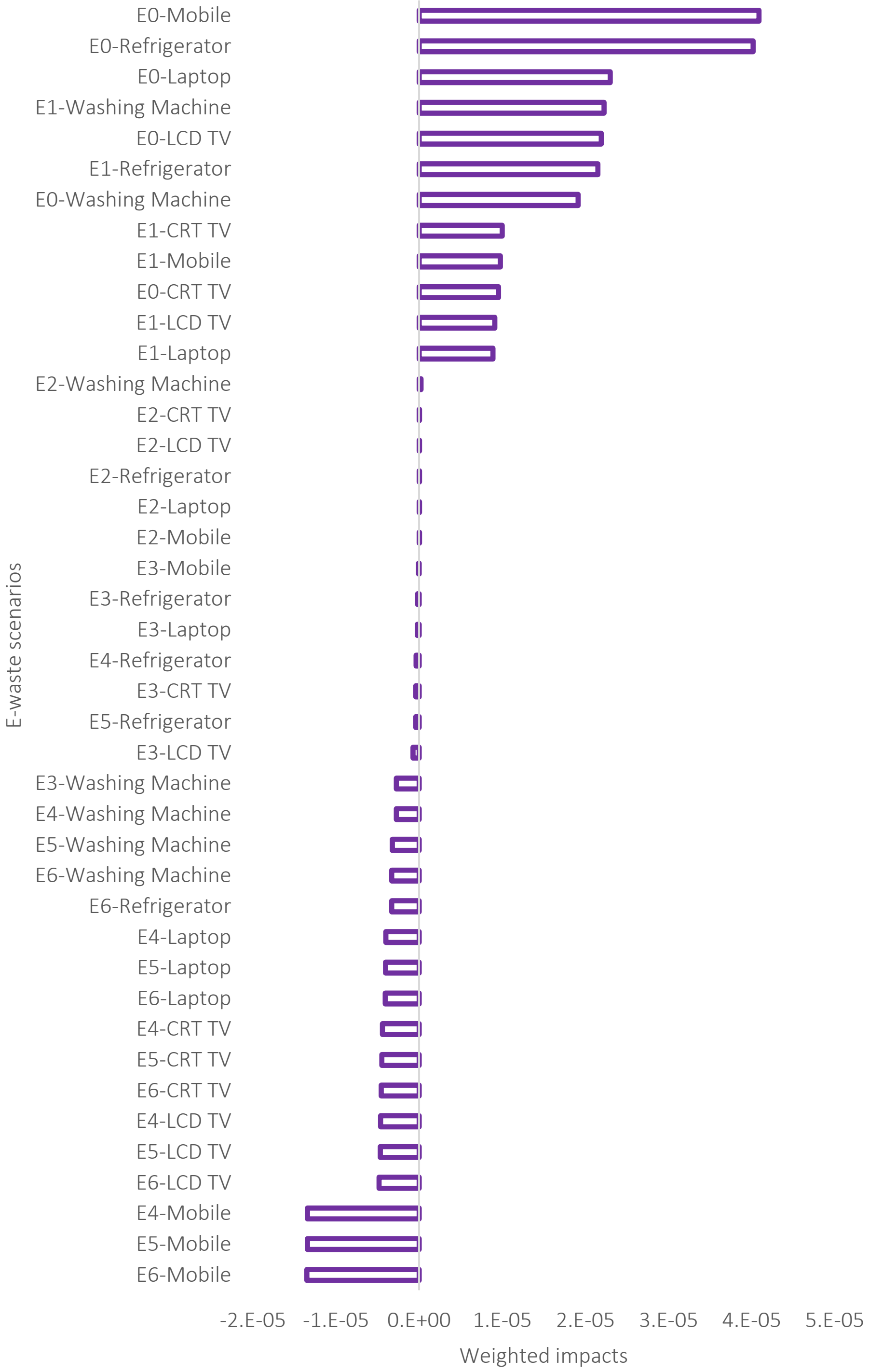

Figure 5-5. Weighted environmental impacts of each CML impacts categories for treatment and disposal of each EEE

(Positive values are “impacts”; Negative values are “benefits”)

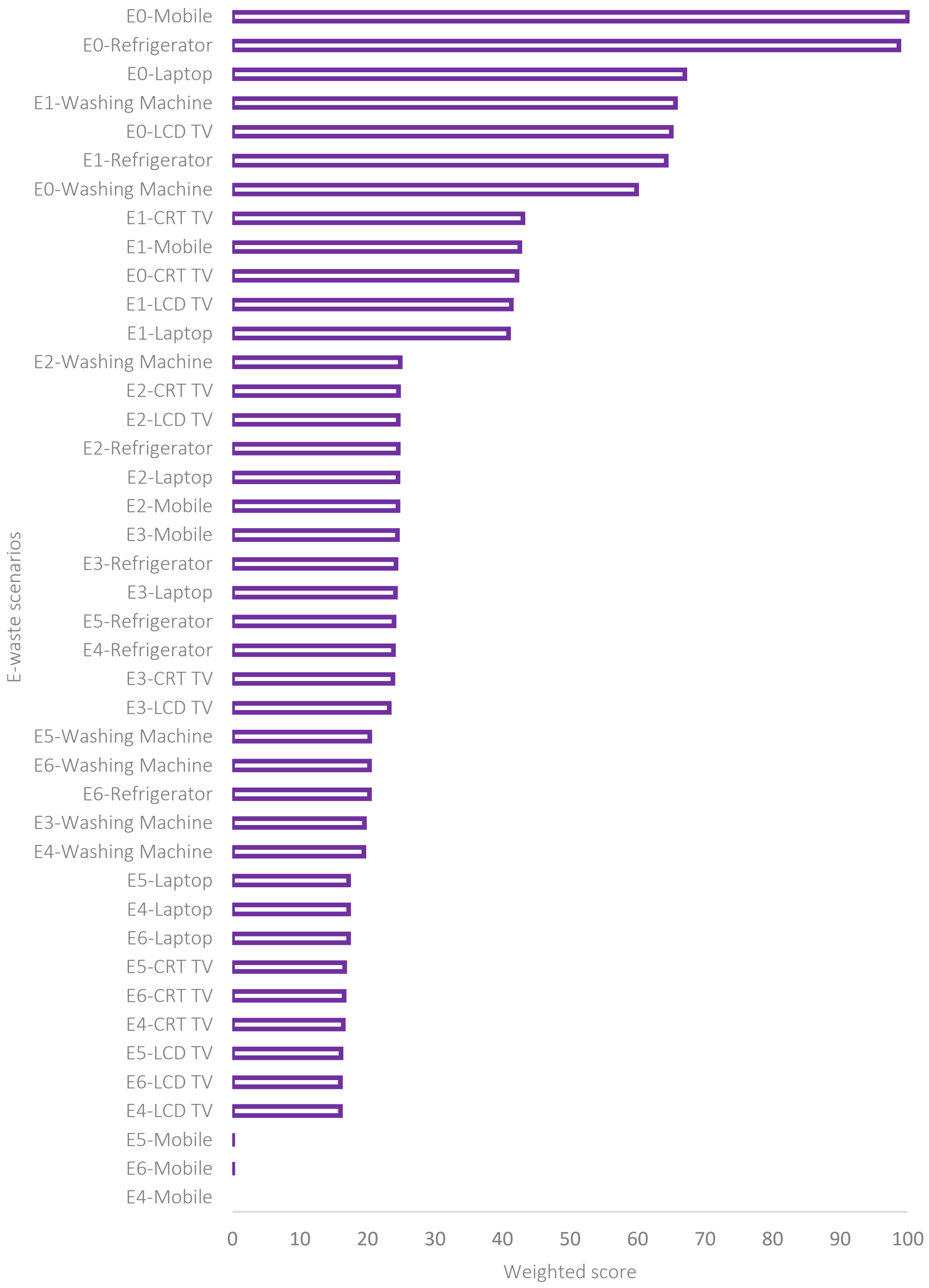

Figure 5-6. Weighted score of e-waste scenarios for treatment and disposal of each EEE

Table 5-4. Weighted environmental impact categories from all scenarios for the entire e-waste stream (CML 2001)

Impact category	E0	E1	E2	E3	E4	E5	E6
RD	N/E	-8.7.E+01	1.3.E-01	-8.7.E+01	-1.4.E+03	-1.5.E+03	-1.5.E+03
AP	1.6.E+03	-4.0.E+03	2.0.E+03	-3.0.E+03	-1.8.E+04	-3.4.E+04	-3.4.E+04
EP	1.8.E+04	2.3.E+03	9.4.E+02	6.6.E+02	-2.6.E+02	-2.4.E+03	-2.4.E+03
FAE	3.3.E+07	2.7.E+07	2.2.E+03	-4.2.E+03	-6.3.E+03	-2.0.E+04	-2.0.E+04
GWP	4.9.E+05	-6.7.E+05	4.8.E+05	-4.4.E+05	-1.3.E+06	4.6.E+06	4.6.E+06
HTP	4.6.E+07	2.2.E+07	2.3.E+04	-9.3.E+05	-1.1.E+06	-1.6.E+06	-1.6.E+06

RD: Resources depletion (abiotic resources; kg Sb-Equiv); AP: Acidification Potential (kg SO2-Equiv); EP: Eutrophication Potential (kg Phosphate-Equiv); FAE: Freshwater Aquatic Ecotoxicity (kg DCB-Equiv); GWP: Global Warming Potential (kg CO_2-Equiv); HTP: Human Toxicity Potential (kg DCB-Equiv). “N/E” denotes “Not estimated”.

Regarding scenario combinations of MSWM and e-waste scenarios (IEWM scenarios), the results are shown in Table 5-5. The results showed that the most promising scenario is Scenario S2-D+E4 (the optimal MSW and e-waste scenario) in which it features recycling of materials, non-precious and precious metals, and sanitary landfill of MSW and the reminder of e-waste with energy recovered from landfilling and waste separation is used at an MRF. The second most promising performance was obtained from Scenario S3-C+E4 in which the scenario features recycling of precious and non-precious metals with waste separation at an MRF. The MSW portion is composited by 10% and biogasified by 10% of the organic fraction while the remainder is landfilled among with the e-waste reminders.

It was noted that scenarios that feature composting or biogasification coupled with recycling of MSW are promising scenarios and should be paid attention when implementing an IEWM system. It can be concluded from the results obtained from Chapter 3 (see Section 4.3.4) and the results presented in Table 5-5 that incineration with energy recovery is a technology that should be paid attention in developing countries in regards to the environmental impacts.

Table 5-5. Weighted scores for the scenario combinations (MSWM and e-waste scenarios)

Scenarios	GWP	AP	EP	FAT	HTP	RD	Weighted impacts	Weighted score
S2-D+E4	-6.72E-02	8.80E-06	1.16E-05	1.04E-04	2.40E-04	-4.85E-02	-1.15E-01	0.00
S3-C+E4	-8.14E-02	1.50E-05	8.46E-06	1.12E-04	3.40E-04	-1.42E-02	-9.51E-02	15.67
S2-C+E4	-6.71E-02	1.50E-05	8.61E-06	1.12E-04	3.16E-04	-1.32E-02	-7.98E-02	27.49
S3-B+E4	-6.71E-02	1.50E-05	8.46E-06	1.13E-04	3.26E-04	-1.23E-02	-7.89E-02	28.24
S3-A+E4	-6.71E-02	1.48E-05	8.98E-06	1.13E-04	3.26E-04	-1.23E-02	-7.89E-02	28.24
S2-B+E4	-6.71E-02	1.56E-05	8.39E-06	1.13E-04	3.16E-04	-1.22E-02	-7.88E-02	28.26
S4+E4	-6.73E-02	3.14E-06	5.98E-06	5.15E-05	1.16E-04	-5.10E-05	-6.72E-02	37.29
S4+E3	-6.73E-02	3.53E-06	6.02E-06	5.15E-05	1.17E-04	-2.70E-05	-6.71E-02	37.31
S4+E2	-6.73E-02	3.66E-06	6.03E-06	5.15E-05	1.19E-04	-2.55E-05	-6.71E-02	37.31
S4+E1	-6.73E-02	3.51E-06	6.08E-06	1.29E-04	1.80E-04	-2.70E-05	-6.70E-02	37.42
S4+E0	-6.73E-02	3.65E-06	6.72E-06	1.46E-04	2.47E-04	-2.55E-05	-6.69E-02	37.48
S0+E4	-6.68E-02	5.27E-06	2.92E-05	1.14E-04	3.93E-04	1.28E-02	-5.35E-02	47.85
S2-D+E6	9.16E-05	4.33E-06	5.54E-06	5.28E-05	1.17E-04	-4.85E-02	-4.82E-02	51.96
S2-D+E5	9.12E-05	4.54E-06	5.56E-06	5.28E-05	1.18E-04	-4.85E-02	-4.82E-02	51.96
S2-D+E3	9.05E-05	5.12E-06	5.66E-06	5.28E-05	1.19E-04	-4.85E-02	-4.82E-02	51.98
S2-D+E2	9.07E-05	5.25E-06	5.68E-06	5.28E-05	1.21E-04	-4.85E-02	-4.82E-02	51.98
S2-D+E1	9.04E-05	5.09E-06	5.73E-06	1.30E-04	1.82E-04	-4.85E-02	-4.81E-02	52.08

Scenarios	GWP	AP	EP	FAT	HTP	RD	Weighted impacts	Weighted score
S2-D+E0	9.07E-05	5.24E-06	6.37E-06	1.47E-04	2.49E-04	-4.85E-02	-4.80E-02	52.15
S3-C+E5	-1.41E-02	1.08E-05	2.40E-06	6.06E-05	2.18E-04	-1.42E-02	-2.80E-02	67.62
S3-C+E3	-1.41E-02	1.14E-05	2.50E-06	6.06E-05	2.18E-04	-1.41E-02	-2.80E-02	67.64
S3-C+E2	-1.41E-02	1.15E-05	2.51E-06	6.07E-05	2.21E-04	-1.41E-02	-2.80E-02	67.65
S3-C+E1	-1.41E-02	1.13E-05	2.56E-06	1.38E-04	2.82E-04	-1.41E-02	-2.78E-02	67.75
S3-C+E0	-1.41E-02	1.15E-05	3.20E-06	1.55E-04	3.49E-04	-1.41E-02	-2.77E-02	67.82
S2-C+E6	2.39E-04	1.05E-05	2.52E-06	6.04E-05	1.92E-04	-1.32E-02	-1.27E-02	79.45
S2-C+E5	2.38E-04	1.07E-05	2.55E-06	6.04E-05	1.93E-04	-1.32E-02	-1.27E-02	79.45
S2-C+E3	2.38E-04	1.13E-05	2.65E-06	6.05E-05	1.94E-04	-1.32E-02	-1.27E-02	79.47
S2-C+E2	2.38E-04	1.15E-05	2.66E-06	6.05E-05	1.97E-04	-1.32E-02	-1.27E-02	79.47
S2-C+E1	2.38E-04	1.13E-05	2.72E-06	1.38E-04	2.58E-04	-1.32E-02	-1.25E-02	79.58
S2-C+E0	2.38E-04	1.14E-05	3.36E-06	1.55E-04	3.24E-04	-1.32E-02	-1.25E-02	79.64
S3-B+E6	2.22E-04	1.06E-05	2.37E-06	6.19E-05	2.03E-04	-1.23E-02	-1.18E-02	80.19
S3-B+E5	2.22E-04	1.08E-05	2.40E-06	6.19E-05	2.04E-04	-1.23E-02	-1.18E-02	80.19
S3-A+E6	2.26E-04	1.03E-05	2.89E-06	6.19E-05	2.03E-04	-1.23E-02	-1.17E-02	80.19
S3-A+E5	2.25E-04	1.05E-05	2.92E-06	6.19E-05	2.04E-04	-1.23E-02	-1.17E-02	80.20
S3-B+E3	2.21E-04	1.14E-05	2.50E-06	6.19E-05	2.05E-04	-1.22E-02	-1.17E-02	80.21
S3-A+E3	2.24E-04	1.11E-05	3.02E-06	6.19E-05	2.05E-04	-1.22E-02	-1.17E-02	80.21

Scenarios	GWP	AP	EP	FAT	HTP	RD	Weighted impacts	Weighted score
S3-B+E2	2.21E-04	1.15E-05	2.51E-06	6.19E-05	2.07E-04	-1.22E-02	-1.17E-02	80.21
S3-A+E2	2.25E-04	1.12E-05	3.03E-06	6.19E-05	2.07E-04	-1.22E-02	-1.17E-02	80.22
S2-B+E6	2.39E-04	1.11E-05	2.30E-06	6.11E-05	1.93E-04	-1.22E-02	-1.17E-02	80.22
S2-B+E5	2.38E-04	1.13E-05	2.33E-06	6.11E-05	1.94E-04	-1.22E-02	-1.17E-02	80.22
S2-B+E3	2.38E-04	1.19E-05	2.43E-06	6.11E-05	1.94E-04	-1.22E-02	-1.17E-02	80.24
S2-B+E2	2.38E-04	1.20E-05	2.44E-06	6.11E-05	1.97E-04	-1.22E-02	-1.17E-02	80.24
S3-B+E1	2.21E-04	1.13E-05	2.56E-06	1.39E-04	2.69E-04	-1.22E-02	-1.16E-02	80.32
S3-A+E1	2.24E-04	1.10E-05	3.08E-06	1.39E-04	2.69E-04	-1.22E-02	-1.16E-02	80.32
S2-B+E1	2.38E-04	1.19E-05	2.50E-06	1.38E-04	2.58E-04	-1.22E-02	-1.15E-02	80.35
S3-B+E0	2.21E-04	1.15E-05	3.20E-06	1.57E-04	3.35E-04	-1.22E-02	-1.15E-02	80.39
S3-A+E0	2.25E-04	1.12E-05	3.72E-06	1.57E-04	3.35E-04	-1.22E-02	-1.15E-02	80.39
S2-B+E0	2.38E-04	1.20E-05	3.14E-06	1.56E-04	3.25E-04	-1.22E-02	-1.15E-02	80.42
S2-A+E6	2.54E-04	1.55E-05	2.42E-06	6.01E-05	2.05E-04	-1.85E-03	-1.31E-03	88.27
S2-A+E4	2.53E-04	1.59E-05	2.51E-06	6.01E-05	2.07E-04	-1.85E-03	-1.31E-03	88.27
S2-A+E5	2.54E-04	1.57E-05	2.45E-06	6.01E-05	2.07E-04	-1.85E-03	-1.31E-03	88.27
S2-A+E3	2.53E-04	1.63E-05	2.55E-06	6.01E-05	2.07E-04	-1.83E-03	-1.29E-03	88.29
S2-A+E2	2.53E-04	1.64E-05	2.56E-06	6.01E-05	2.10E-04	-1.83E-03	-1.28E-03	88.30
S2-A+E1	2.53E-04	1.63E-05	2.62E-06	1.37E-04	2.71E-04	-1.83E-03	-1.15E-03	88.40

Scenarios	GWP	AP	EP	FAT	HTP	RD	Weighted impacts	Weighted score
S2-A+E0	2.54E-04	1.64E-05	3.26E-06	1.55E-04	3.37E-04	-1.83E-03	-1.06E-03	88.47
S3-C+E6	-1.41E-02	-1.23E-05	-2.57E-06	-6.07E-05	-2.25E-04	1.41E-02	-3.26E-04	89.04
S4+E6	7.30E-07	-1.34E-06	-1.11E-07	-7.44E-08	-7.52E-06	-5.19E-05	-6.02E-05	89.24
S4+E5	3.41E-07	-1.12E-06	-8.30E-08	-5.58E-08	-6.12E-06	-5.10E-05	-5.80E-05	89.24
S1+E6	3.28E-04	4.62E-06	1.61E-05	6.29E-05	2.20E-04	1.28E-02	1.34E-02	99.66
S1+E4	3.26E-04	5.02E-06	1.62E-05	6.30E-05	2.22E-04	1.28E-02	1.34E-02	99.67
S1+E5	3.27E-04	4.83E-06	1.62E-05	6.29E-05	2.22E-04	1.28E-02	1.34E-02	99.67
S1+E3	3.27E-04	5.41E-06	1.63E-05	6.30E-05	2.22E-04	1.28E-02	1.34E-02	99.69
S1+E2	3.27E-04	5.54E-06	1.63E-05	6.30E-05	2.25E-04	1.28E-02	1.34E-02	99.69
S1+E1	3.27E-04	5.39E-06	1.63E-05	1.40E-04	2.86E-04	1.28E-02	1.36E-02	99.79
S0+E6	4.54E-04	7.99E-07	2.31E-05	6.26E-05	2.70E-04	1.28E-02	1.36E-02	99.80
S0+E5	4.54E-04	1.01E-06	2.31E-05	6.27E-05	2.71E-04	1.28E-02	1.36E-02	99.80
S0+E3	4.53E-04	1.59E-06	2.32E-05	6.27-05	2.72E-04	1.28E-02	1.36E-02	99.82
S0+E2	4.54E-04	1.72E-06	2.32E-05	6.27E-05	2.74E-04	1.28E-02	1.36E-02	99.83
S1+E0	3.27E-04	5.53E-06	1.70E-05	1.58E-04	3.53E-04	1.28E-02	1.37E-02	99.86
S0+E1	4.53E-04	1.56E-06	2.33E-05	1.40E-04	3.36E-04	1.28E-02	1.37E-02	99.93
S0+E0	4.54E-04	1.71E-06	2.39E-05	1.57E-04	4.02E-04	1.28E-02	1.38E-02	100.00

GWP: Global Warming Potential; AP: Acidification Potential; EP: Eutrophication Potential; FAE: Freshwater Aquatic Ecotoxicity; HTP: Human Toxicity Potential; RD: Resources depletion (abiotic resources).

5.5. Conclusion of Chapter 5

Based on the IEWM approach proposed in Chapter 2, this chapter evaluated the current improper practices and advanced state-of-the-art technologies of e-waste management for developing countries. Jordan was used as a case study, in which the environmental impacts of the current e-waste practices were found significant. The results showed that the environmental impacts depended on the climate conditions (e.g. arid or humid climate). In Jordan’s climate (semi-arid to arid climate), it was found that the fate of the emission is mostly to air. The best e-waste management scenario was sanitary landfilling with both metal and precious metals recycling and incineration of plastic and PCBs. It was found that improving the current situation by prohibiting open burning and introducing a recycling scheme of metals can improve the situation significantly. The weighted score of such a scenario was 61 compared with 100 in which the lower the score becomes, the better the environmental performance is. Introducing sanitary landfill and prohibiting unsanitary landfill and open dump can significantly improve the situation (its score was evaluated at 18). Regarding scenario combinations, it was found that the best-integrated e-waste management scenario regarding environmental impacts is the one that features recycling of materials of the MSW stream and non-precious and precious metals from e-waste with separation of MSW is used at an MRF. In this scenario, sanitary landfill of both waste reminders of MSW and e-waste is used with energy recovery. The results showed that biogasification, composting, and incineration with energy recovery are technologies that also should be paid attention in developing countries when implementing an IEWM system.

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6. CONCLUSION

6.1. Overall Conclusion

This dissertation aimed at contributing to the need for e-waste management policies and the development and evaluation of integrated e-waste management programs for developing countries.

Developing countries are facing huge challenges in managing e-waste in which the amount of generated e-waste is increasing. In many developing countries, especially low-income and middle-income countries, a significant portion of e-waste components finds its destination to unsanitary (uncontrolled) landfill sites. Similarly, informal recycling of e-waste is widely practiced. For example, wires are burned in open spaces to remove plastic and recover copper. Acid extraction is also practiced to recover precious metals from PCBs. Such practices can be notably seen in China, India, Pakistan, Vietnam, Philippines, Nigeria, and Ghana; where the e-waste is split apart by poor people using primitive methods to retrieve valuable metals and do not have facilities to protect the environment and public wellness. Therefore, a literature review for the concept of the IWM was conducted in Chapter 2. Fifty-seven peer-reviewed articles and reports were reviewed to investigate the emergence, the development, and the utilization of the IWM approach for modern waste management systems. The aim of the review was to propose an approach to solving e-waste management issues by utilization of the IWM concept. The major findings from Chapter 2 were: (1) IWM is an emerging concept in many developing countries, (2) Many researchers tend to use the term "IWM" without a clear definition while utilizing the concept from a technical aspect rather than to define it. Defining the concept is significant because it differentiates between both the traditional and the integrated concepts and it facilitates the concept's development and its implementation, and (3) IWM must supplant the traditional approach to responding to the needs of current modern societies. That is because the traditional MSW approach is no longer capable of dealing with complex issues and cannot achieve proper effective waste management. The concept of IWM was defined in this dissertation. It was defined as "a systematic life cycle thinking approach that considers the entire waste management system, the waste hierarchy, and incorporation of different components of waste management from prevention to final disposal. It combines different waste streams, treatment and disposal methods. It aims to improve the current waste management practices by achieving social acceptance, minimizing environmental burdens, and maximizing economic benefits.”. Based on the reviewed literature, a systematic approach to solutions of the complex nature of e-waste related issues in developing countries was needed. An integrated e-waste management (referred to as “IEWM”) approach was thus, proposed. The IEWM aims (1) to address the issue in which both MSW and e-waste streams are mixed, (2) to utilize the existing MSW infrastructure to deal with both waste streams, and (3) to achieve environmental and economic benefits. It was found that both MSW and e-waste streams share common waste treatment and disposal methods. Thus, this dissertation addressed environmental minimization and economic optimization by applying the IWM concept to both MSW and e-waste. This approach places emphasis on the EoL of EEE products on which the dangerous situation of e-waste disposal occurs. The IEWM approach requires the following steps: (1) examination of the e-waste estimation methods for selection of suitable method as was achieved in Chapter 3, (2) establishing both economic and environmental evaluation of MSWM systems in developing countries (Chapter 4), and (3) evaluation of environmental loads and cost of the present e-waste management practices compared with advanced mitigating technologies (Chapter 5).

Thus, in Chapter 3, five existing methods employed for e-waste estimations in developing countries were examined. The C&U method, a widely utilized method for e-waste estimation in developing countries was modified to address its drawbacks in which it underestimates the quantity of e-waste generated and it took secondhand products into account. Two modified versions of the C&U method, using Jordan’s e-waste data, were introduced. The comparison concluded that the estimation methods must be applied cautiously, depending on the market conditions (saturated, unsaturated and fast-growing with short lifespans). For example, it was found that the C&U method is applicable where data are scarce and to build a basic e-waste estimation for saturated appliances where the saturation level is close to one. This study suggests utilization of the proposed method to for developing countries to establish an e-waste assessment inventory. Drawn upon the requirement of the proposed IEWM approach in Chapter 2, the LCA method was employed to estimate and evaluate the environmental impacts of both the MSWM and the e-waste scenarios in Chapters 4 and 5. With regards to MSWM (Chapter 4), it was found that improving the current MSWM practices by getting in a recycling system with waste separation at an MRF combined with sanitary landfill with energy recovery was the most promising scenario regarding both the environmental impacts and the cost (the cost recovered was over than 100%). Nevertheless, the study recommends that sanitary landfill is to be used for disposal of residues. Diversion of waste that goes to landfill sites can recover several metals in which it improves the environmental impacts and conserves resources. Referable to the high financial value of modern waste treatment technologies (e.g., incinerators), sanitary landfill with energy recovery, when matched with a proper sorting and recycling system, seems a worthy choice for developing countries. This study stressed the use of energy recovery from landfill sites with proper recovery efficiency if landfill to be applied as well as a proper gas collection at landfill sites. The study also suggests that scenarios comprising composting, biogasification or both should be paid attention regarding the environmental impacts and the economic performance. They are also recommended due to the high fraction of the organic waste. With regards to e-waste (Chapter 5), emissions from the current waste management system were mainly for air and soil due to the arid nature of Jordan’s climate, and they are significant. The major contributors to emissions are PCBs by toxic substances (arsenic, lead, antimony, chromium, cadmium, and mercury) from unsanitary sites, open dump sites, and open burning respectively and they contribute to 39.3% of the aggregate emissions. Human toxicity and acidification potentials were found significant in the current situation and practically when compared with alternative e-waste handling options. It was found that improving the current situation by prohibiting open burning and putting in a recycling system of metals can improve the situation significantly. The weighted score of such a scenario was 61 compared with 100 in which the higher the score goes, the more severe the environmental performance is. Introducing sanitary landfill and prohibiting unsanitary landfill and open dump ameliorate the situation (its score was evaluated at 18). It was found that introducing recycling of precious metals to an existing recycling scheme can significantly mitigate the environmental impacts. It should be noted that the study considered the environmental impacts of recycling comparing saving impacts from the production of same virgin materials (the score was 2.1). In regards to PCBs incineration or landfilling, it was found that incineration with energy recovery with well-established incineration infrastructure seems better than landfilling, but the performance of the total examined environmental impacts was closely similar.

It was found that the best integrated e-waste management scenario regarding environmental impacts is the one that features recycling of materials of the MSW stream and non-precious and precious metals from e-waste with separation of MSW is used at an MRF. In this scenario, sanitary landfill of both waste reminders of MSW and e-waste is used with energy recovery. The results showed that biogasification, composting, and incineration with energy recovery are technologies that also should be paid attention in developing countries when implementing an IEWM system.

The contribution of this dissertation is as follows:

First, a proposed e-waste estimation method that applies to developing countries and addresses the existing issues with other methods, practically with data availability and underestimation of e-waste; a method that suggested for its application to the entire e-waste stream was presented. This contribution of the study is because it can help those countries to launch e-waste assessment programs to infer the present situation of e-waste generation and to establish proper plans for handling e-waste.

Second, this study contributes to providing a systematic procedure for e-waste management and baseline information on its management operations; those that handle e-waste improperly as well as advanced processes. Therefore, this dissertation attempted to fill the major gap in which knowledge about the environmental and health impacts of e-waste management is limited or lacking in developing countries. The results can raise the awareness level about the diverse environmental and health impacts of e-waste management and to provoke countries to take actions. The results, as well, provide baseline information on the environmental and health impacts of advanced technologies such as recycling facilities, well-engineered landfill sites, and modern incineration plants that can isolate the environmental impacts and generate efficient electricity.

In summary, this dissertation helps to estimate and mitigate environmental damages caused by the improper e-waste management in developing countries. The study considered environmental impacts and benefits of state-of-the-art technologies for developing countries with a comparison to the present improper e-waste practices.

6.2. Prospects for Future Studies

Though this dissertation filled several gaps in the existing studies regarding e-waste management in developing countries, especially in Jordan, the below points might be regarded as limitations.

1. Although all the required data for conducting this study was acquired from various resources through two field trips to Jordan, literature, online resources, and LCI data; data on waste composition and substance composition of EEE were limited to developed countries mostly. Hence, studies to characterize the waste composition and the substances of EEE are encouraged in the case of developing countries.
2. The traditional and current waste management scheme was considered in this study. However, various waste management collection schemes and for the individual waste management scenarios were not examined. Waste collection strategies can help to develop IWM programs. MFAs were utilized in the waste management systems for this study in which they have the functionality of waste separation. However, various types of MRFs were not considered. In general, this study suggests the below waste collection and sorting schemes for an IEWM system.

    a) A collection of deposit containers.

    b) A collection of deposit containers and collection with drop-off center.

    c) Sorted recyclables MRF, manual or mechanical.

    d) Mixed recyclable MRF, manual or mechanical.

3. This study considered semi-arid to arid climate conditions which might be typical of many countries in the MENA region in which Jordan is located. Nevertheless, investigating how different climate conditions influence the results would be a future research topic (e.g. semi-humid and humid climate).
4. Due to difficulties to set up multiple parameters, sensitivity and uncertainty analysis were not conducted, and they were out of the scope of the study. Yet, both methods should be applied to examine the presumptions made for their influence on the overall outcomes.

Considering the findings and the limitations of this study, the future work is planned to address the limitations of the study and to develop (WFs) as specific factors for environmental impact assessment are completely lacking for developing countries. The possible and existing factors are, for example, European or global average. Second, to employ the LCA method to assess the present and improper e-waste management practices of 14 developing MENA region's countries as a case study for the developing countries by utilization of the developed WFs. The purpose of the ranking is to provoke developing countries for taking an action and to motivate for policy making.

APPENDICES

Appendix A: Historical sales data of PC used in Chapter 3

Source of data: Jordan Department of Statistics (JDoS)

Year	Sales of desktop computer (units)	Sales of laptop computer (units)
1998	1,660	1,527
1999	3,212	5,409
2000	11,623	6,954
2001	27,056	2,950
2002	21,926	3,440
2003	34,779	3,217
2004	26,245	9,160
2005	33,848	10,210
2006	68,584	17,207
2007	92,162	38,859
2008	132,457	75,451
2009	110,595	126,734
2010	81,999	146,062
2011	74,483	133,463

Year	Sales of desktop computer (units)	Sales of laptop computer (units)
2012	69,320	90,566
2013	141,101	115,019

Appendix B: Penetration rates per household of each EEE used in Chapter 3

Source of data: JDoS

Year	PC	Mobile	TV	Refrigerator	Washing machine
1997	9.0%	10.0%	92.4%	92.4%	88.9%
1998	9.0%	15.0%	92.4%	92.4%	92.4%
1999	9.0%	15.0%	92.4%	92.4%	92.4%
2000	10.0%	20.8%	93.4%	93.0%	92.9%
2001	10.0%	20.8%	93.4%	92.9%	92.9%
2002	10.0%	36.8%	96.4%	93.4%	95.1%
2003	21.0%	47.4%	97.2%	94.0%	94.8%
2004	21.0%	47.4%	97.2%	93.8%	94.8%
2005	22.0%	51.3%	98.2%	95.0%	96.0%
2006	22.0%	51.3%	98.2%	96.0%	96.0%
2007	32.0%	84.1%	98.2%	97.1%	97.0%
2008	36.3%	93.7%	98.7%	97.2%	97.3%
2009	36.3%	93.7%	98.7%	97.2%	97.3%
2010	36.3%	93.7%	98.7%	97.2%	97.3%
2011	35.3%	98.1%	98.9%	98.1%	97.9%
2012	35.4%	98.2%	98.9%	98.1%	97.9%

Year	PC	Mobile	TV	Refrigerator	Washing machine
2013	35.4%	98.2%	98.9%	98.1%	97.9%

Appendix C: Calculated sales data used in Chapter 3

Calculated based on data obtained from JDoS and UN Comtrade online database. Data on production, import, and export were extracted to calculate the sales for each appliance through the Harmonized System Codes (HS Code).

Year	Washing machine	Refrigerator	TV	Desktop	Notebook	Mobile Phone	Total sales
1994	23,704	12,142	240,68				59,914
1995	23,415	15,911	26193				65,519
1996	28,011	13,682	32,997				74,690
1997	19,728	8,582	15,317			44,609	88,236
1998	33,379	10,432	72,610	1,660	1,527	82,289	201,897
1999	35,253	15,528	83,009	3,212	5,409	119,398	261,809
2000	52,203	23,973	43,796	11,623	6,954	113,237	251,786
2001	72,711	28,549	80,805	27,056	2,950	254,589	466,660
2002	109,488	35,212	117,490	21,926	3,440	362,249	649,805
2003	133,331	24,318	117,490	34,779	3,217	397,331	710,466
2004	185,597	34,930	254,372	26,245	9,160	487,461	997,765
2005	357,701	61,790	85,908	33,848	10,210	936,508	1,485,965
2006	350,946	73,434	78,387	68,584	17,207	1,280,000	1,868,558
2007	295,849	46,520	223,612	92,162	38,859	1,379,570	2,076,572
2008	283,808	44,995	117,450	132,457	75,451	1,502,447	2,156,608
2009	249,353	140,093	213,748	110,595	126,734	1,662,440	2,502,963

Year	Washing machine	Refrigerator	TV	Desktop	Notebook	Mobile Phone	Total sales
2010	259,277	76,421	198,263	81,999	146,062	1,791,284	2,553,306
2011	242,288	155,718	239,662	74,483	133,463	1,984,682	2,830,296
2012	234,410	209,025	159,934	69,320	90,566	2,339,286	3,102,541
2013	203,708	162,514	174,302	141,101	115,018	2,645,583	3,442,227

Appendix D: Parameters for e-waste estimations used in Chapter 3

EEE	Cell phone	Regular phone	Smart phone	Desktop computer	Laptop computer	TV	Refrigerator	Washing machine
Household penetration rate (2013)	0.98	0.58	0.42	0.43	0.31	0.99	0.98	0.98
Source	JDoS [9]	JDoS	JDoS	calculated	calculated	JDoS	JDoS	JDoS
Penetration rate per person (2013)	1	0.6	0.4	0.24	0.24	0.3	0.24	0.23
Source	JDoS	calculated	calculated	calculated	calculated	calculated	calculated	calculated
Average number of EEE per household (2013)	5.34	3.07	2.24	1.4	1.4	1.6	1.3	1.25
Source	(Fraige et al, 2009)	calculated based on (Fraige et al, 2009)	calculated based on (Fraige et al, 2009)	calculated based on (Fraige et al, 2009)	calculated based on (Fraige et al, 2009)	(Fraige et al, 2009)	(Fraige et al, 2009)	(Fraige et al, 2009)

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[9] Jordan Department of Statistics

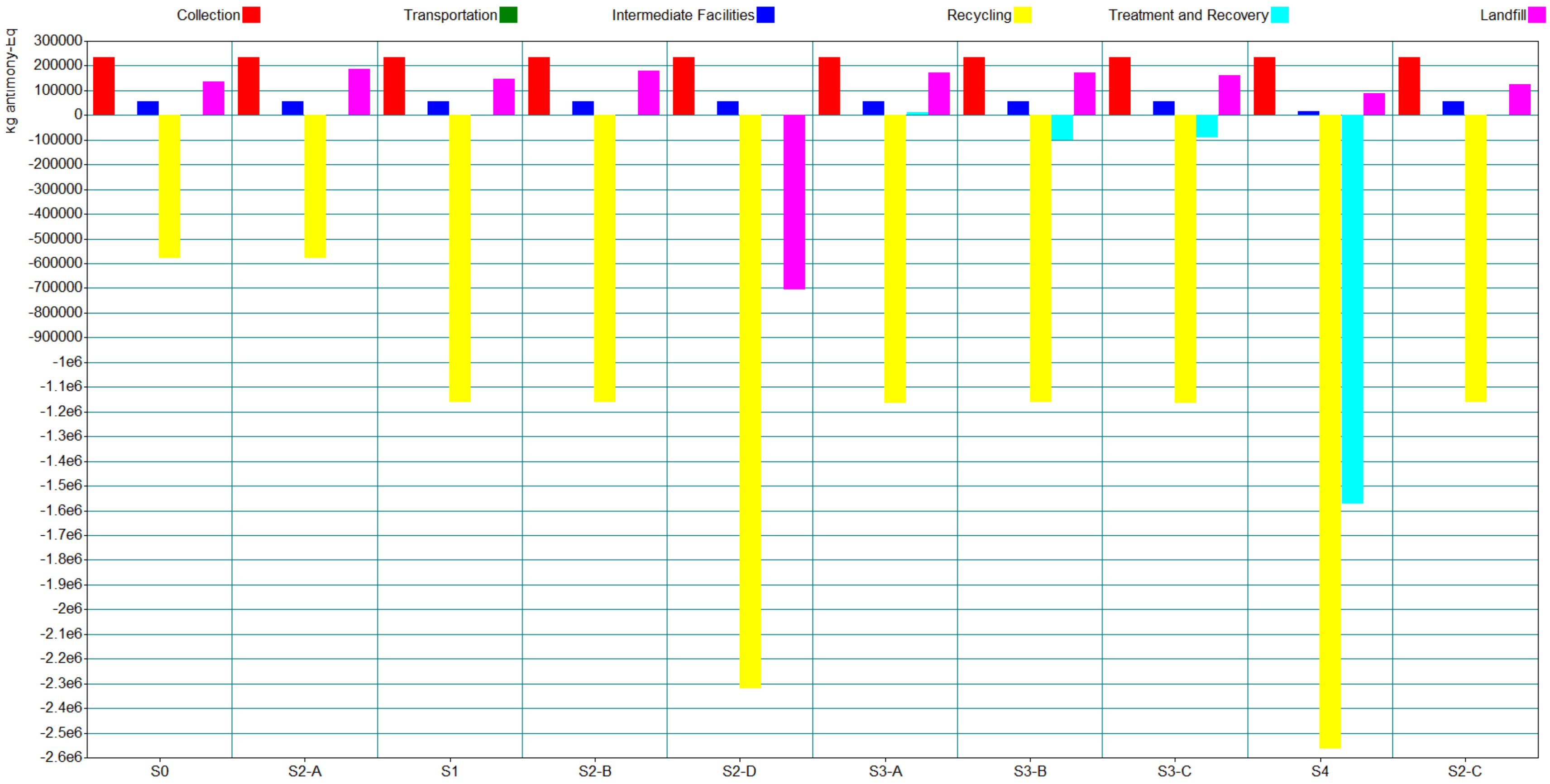
EEE	Cell phone	Regular phone	Smart phone	Desktop computer	Laptop computer	TV	Refrigerator	Washing machine
Average number of EEE per person	0.98	0.56	0.41	0.14	0.10	0.26	0.21	0.21
Source	calculated	calculated	calculated	calculated	calculated	calculated	calculated	calculated
Weight (kg)	0.1	0.1	0.2	22	3.0	30	85	40
Source	(Alavi et al., 2015)	(Alavi et al., 2015)	estimate	(Alavi et al., 2015)	(Alavi et al., 2015)	(Alavi et al., 2015)	(Alavi et al., 2015)	(Alavi et al., 2015)
Weight without monitor (kg)				10				
Source				(Alavi et al., 2015)				
Lifespan (year)	3	3	3	6	6.5	10.5	11.8	9.3

EEE	Cell phone	Regular phone	Smart phone	Desktop computer	Laptop computer	TV	Refrigerator	Washing machine
Source	(Fraige et al, 2009)	(Fraige et al, 2009)	estimate	(Fraige et al, 2009)	(Fraige et al, 2009)	(Fraige et al, 2009)	(Fraige et al, 2009)	(Fraige et al, 2009)

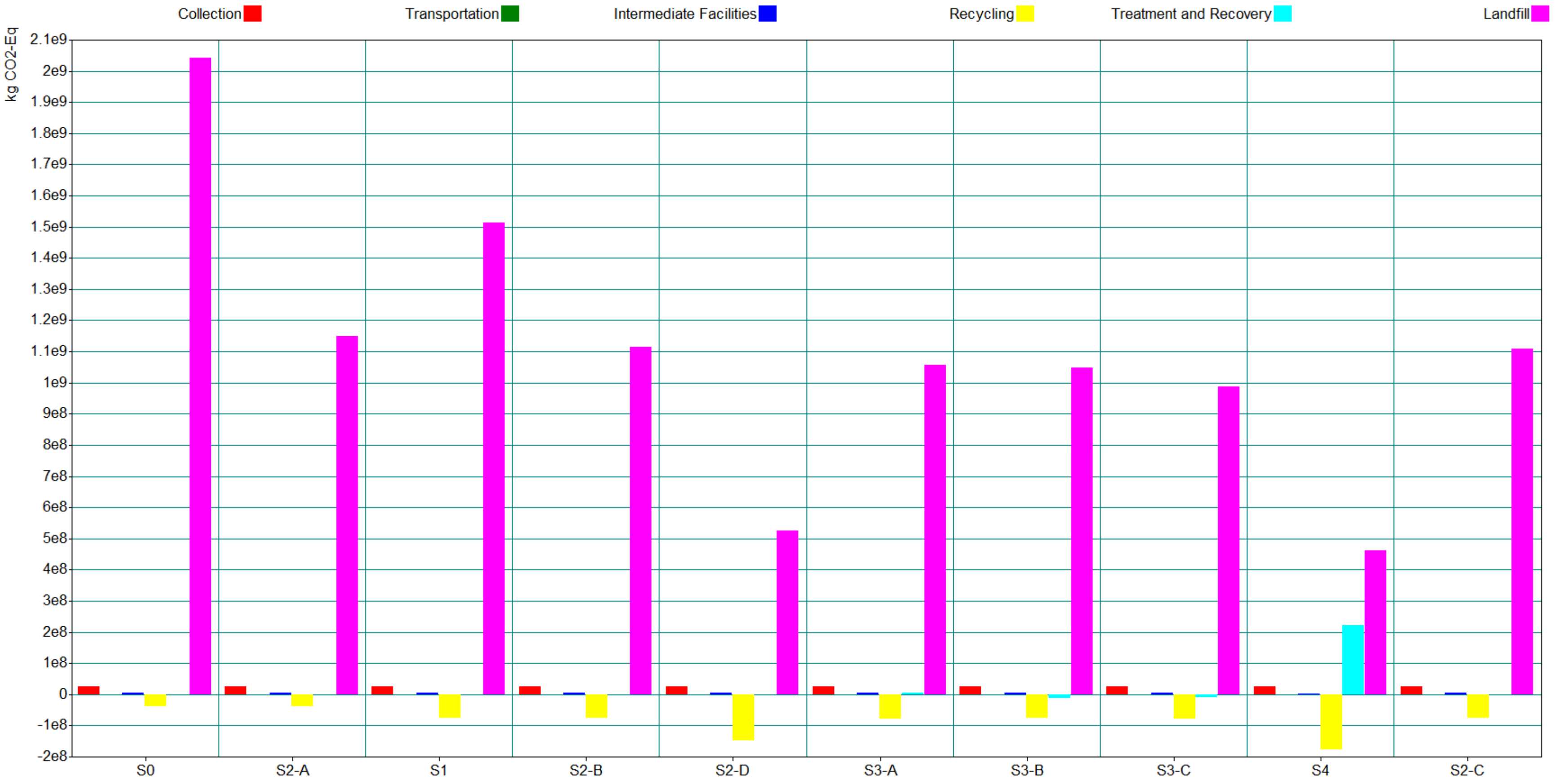
Appendix E: Estimated market share for each eee used in Chapter 3

EEE status	EEE	Market share
New	Mobile	91.0%
	Desktop computer	57.0%
	Laptop computer	30.0%
	TV	92.6%
	Washing Machine	90.5%
	Refrigerator	87.7%
Secondhand	Mobile	9.0%
	TV	7.4%
	Washing Machine	9.5%
	Refrigerator	12.3%
	Desktop computer	9.0%
	Laptop computer	4.0%

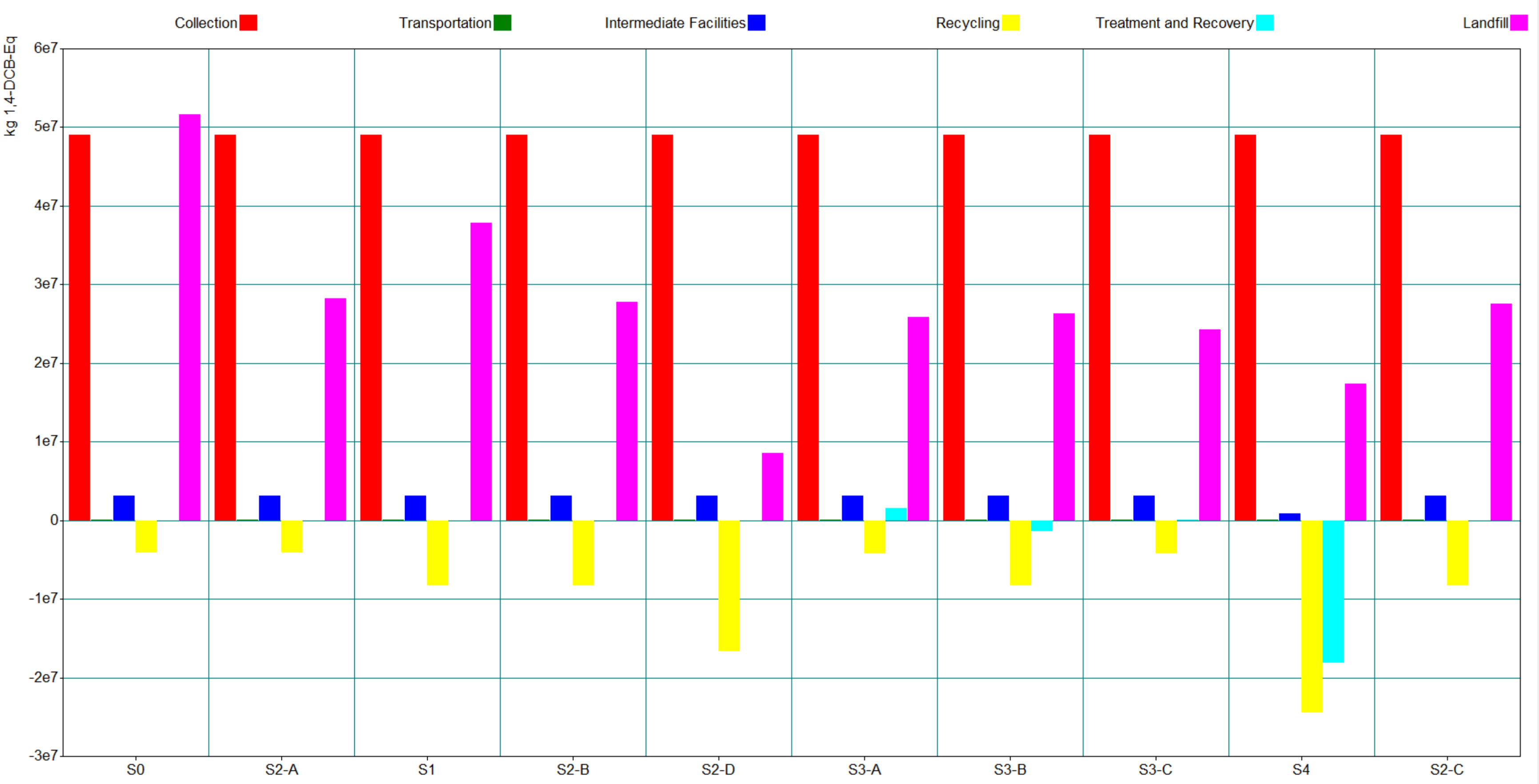
Appendix F: Depletion of abiotic resources



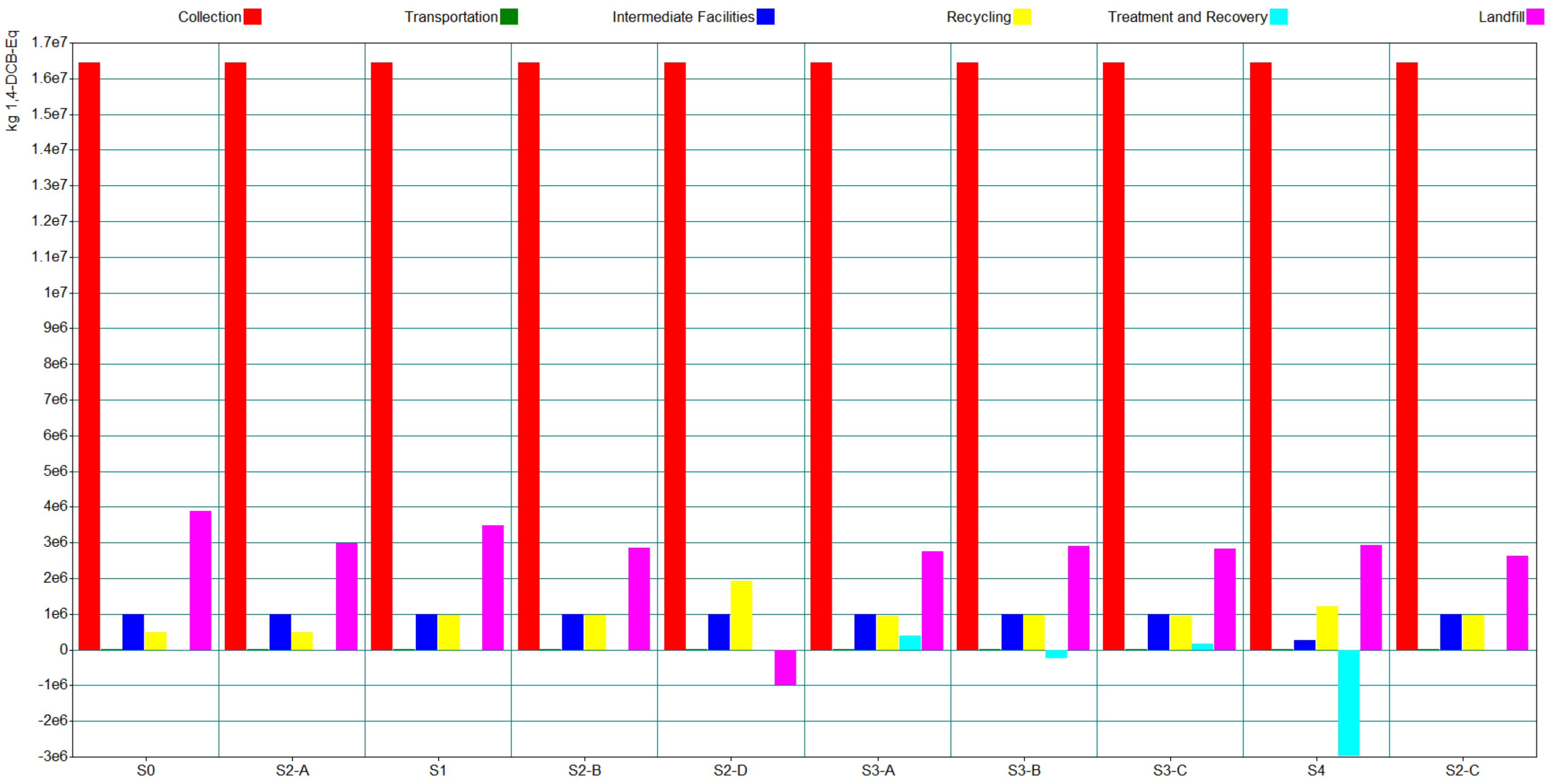
Appendix G: Climate change: GWP 100a



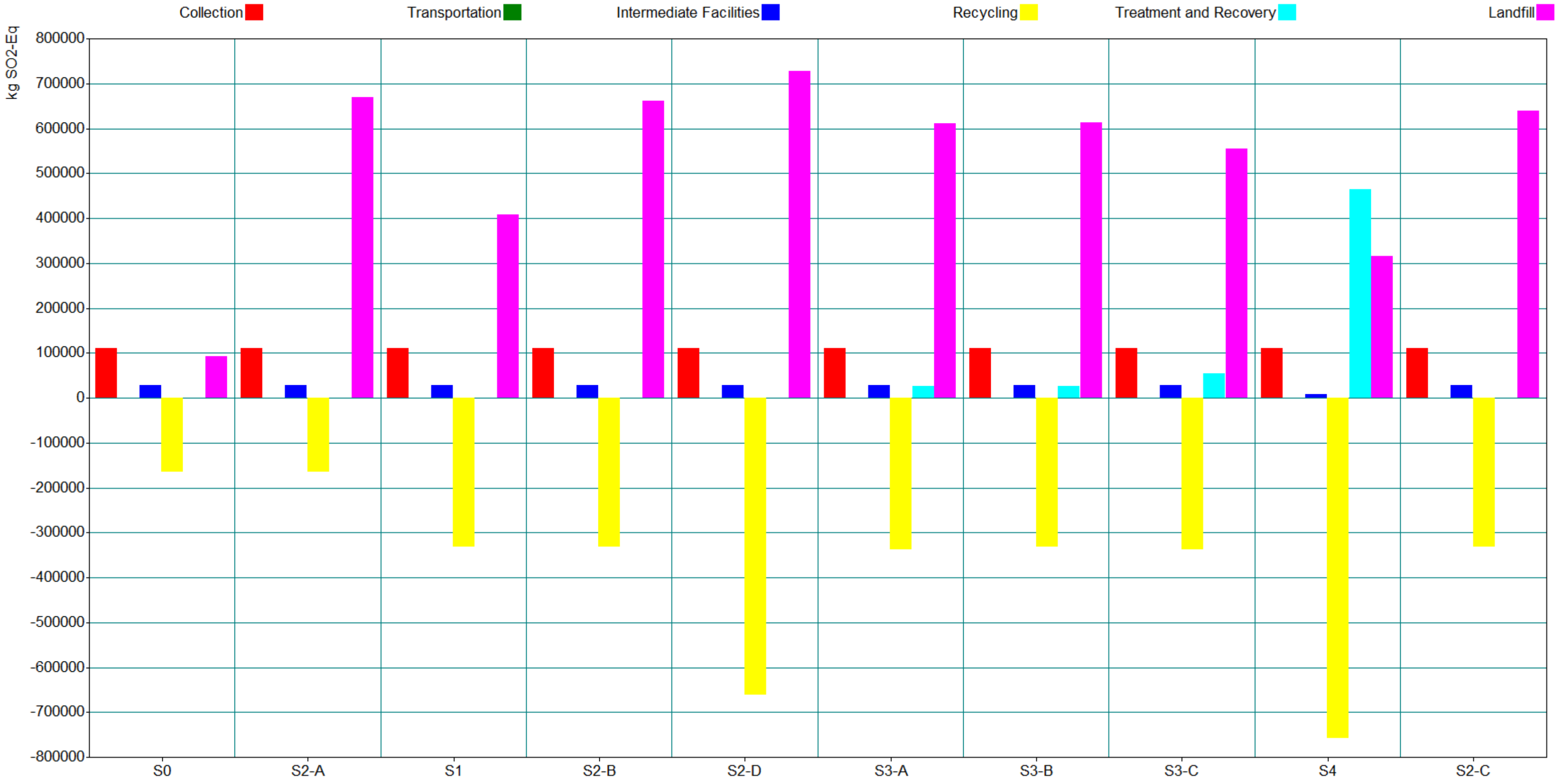
Appendix H: Human toxicity potential



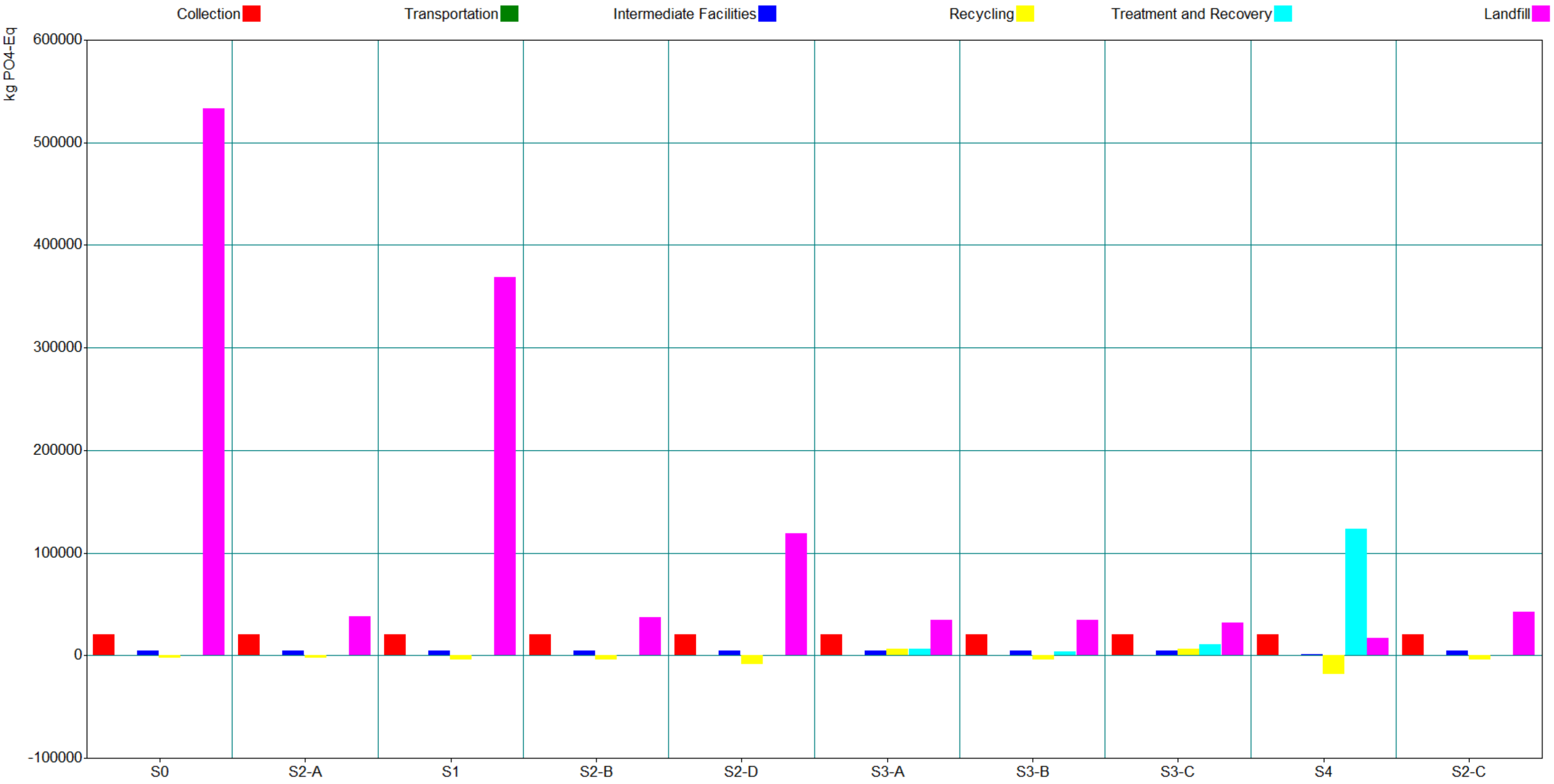
Appendix I: Freshwater aquatic ecotoxicity



Appendix J: Acidification potential



Appendix K: Eutrophication potential



Appendix L: Life Cycle Inventory (LCI) of the Municipal Solid Waste Management (MSWM) scenarios

(For Chapter 4)

Emissions for 2077215 t of the solid waste. EC denotes “Emission category.”

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Heat, waste	air	MJ	-1.E+08	-7.E+08	-9.E+07	-7.E+08	-8.E+08	-3.E+09	-7.E+08	-8.E+08	-8.E+08	-5.E+09
Energy, gross calorific value, in biomass	resource	MJ	-4.E+08	-8.E+08	-4.E+08	-8.E+08	-8.E+08	-2.E+09	-1.E+09	-8.E+08	-1.E+09	-2.E+09
Occupation, forest	resource	m2a	-4.E+07	-9.E+07	-4.E+07	-9.E+07	-9.E+07	-2.E+08	-9.E+07	-9.E+07	-9.E+07	-2.E+08
Carbon dioxide, in air	resource	kg	-4.E+07	-7.E+07	-4.E+07	-7.E+07	-7.E+07	-1.E+08	-1.E+08	-7.E+07	-1.E+08	-1.E+08
Gas, natural, in ground	resource	Nm3	-6.E+06	-2.E+07	-6.E+06	-2.E+07	-2.E+07	-8.E+07	-2.E+07	-2.E+07	-2.E+07	-1.E+08
Carbon dioxide, fossil	air	kg	1.E+07	-2.E+07	1.E+07	-2.E+07	-3.E+07	-2.E+08	-3.E+07	-4.E+07	-4.E+07	8.E+07
Oil, crude, in ground	resource	kg	-3.E+06	-2.E+07	-1.E+06	-1.E+07	-1.E+07	-4.E+07	-1.E+07	-2.E+07	-2.E+07	-5.E+07
Energy, potential, stock, in	resource	MJ	4.E+06	-1.E+07	4.E+06	-1.E+07	-1.E+07	-5.E+07	-1.E+07	-1.E+07	-1.E+07	-4.E+07

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
barrage water												
Heat, waste	water	MJ	2.E+06	-1.E+07	3.E+06	-1.E+07	-1.E+07	-4.E+07	-1.E+07	-1.E+07	-1.E+07	-4.E+07
Coal, hard, unspecified, in ground	resource	kg	2.E+06	-6.E+06	2.E+06	-6.E+06	-6.E+06	-2.E+07	-6.E+06	-6.E+06	-6.E+06	-4.E+07
Krypton-85	air	kBq	-1.E+06	-3.E+06	-1.E+06	-3.E+06	-3.E+06	-6.E+06	-3.E+06	-3.E+06	-3.E+06	-2.E+07
Coal, brown, in ground	resource	kg	-3.E+05	-3.E+06	-3.E+05	-3.E+06	-3.E+06	-8.E+06	-3.E+06	-3.E+06	-3.E+06	-8.E+06
Kaolinite, 24% in crude ore, in ground	resource	kg	-1.E+06	-3.E+06	-1.E+06	-3.E+06	-3.E+06	-5.E+06	-3.E+06	-3.E+06	-3.E+06	-5.E+06
Volume occupied, reservoir	resource	m3a	-9.E+05	-2.E+06	-8.E+05	-2.E+06	-2.E+06	-4.E+06	-2.E+06	-2.E+06	-2.E+06	-4.E+06
Occupation, traffic area, road network	resource	m2a	-6.E+05	-1.E+06	-6.E+05	-1.E+06	-1.E+06	-3.E+06	-1.E+06	-1.E+06	-1.E+06	-3.E+06
Peat, in ground	resource	kg	-3.E+05	-6.E+05	-3.E+05	-6.E+05	-6.E+05	-1.E+06	-3.E+06	-6.E+05	-3.E+06	-1.E+06
Water, cooling, unspecified natural origin	resource	m3	-3.E+05	-9.E+05	-3.E+05	-9.E+05	-9.E+05	-2.E+06	-9.E+05	-9.E+05	-9.E+05	-2.E+06

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Heat, waste	soil	MJ	-3.E+05	-8.E+05	-3.E+05	-8.E+05	-8.E+05	-2.E+06	-8.E+05	-8.E+05	-8.E+05	-2.E+06
Transformation, from forest	resource	m^2	-3.E+05	-6.E+05	-3.E+05	-6.E+05	-6.E+05	-1.E+06	-6.E+05	-6.E+05	-6.E+05	-1.E+06
Transformation, to forest	resource	m^2	-3.E+05	-6.E+05	-3.E+05	-6.E+05	-6.E+05	-1.E+06	-6.E+05	-6.E+05	-6.E+05	-1.E+06
Methane, fossil	air	kg	-1.E+05	-4.E+05	-1.E+05	-4.E+05	-4.E+05	-9.E+05	-4.E+05	-4.E+05	-4.E+05	-1.E+06
Talc, in ground	resource	kg	-2.E+05	-4.E+05	-2.E+05	-4.E+05	-4.E+05	-8.E+05	-4.E+05	-4.E+05	-4.E+05	-8.E+05
Strontium-90	water	kBq	-6.E+04	-4.E+05	-5.E+04	-4.E+05	-4.E+05	-1.E+06	-4.E+05	-4.E+05	-4.E+05	-9.E+05
Carbon monoxide, fossil	air	kg	2.E+05	-8.E+04	2.E+05	-8.E+04	-8.E+04	-6.E+05	-8.E+04	-8.E+04	-7.E+04	-1.E+06
Sulphur dioxide	air	kg	-6.E+03	-1.E+05	3.E+03	-1.E+05	-1.E+05	-3.E+05	-1.E+05	-1.E+05	-1.E+05	-3.E+05
Xenon-133	air	kBq	1.E+05	-1.E+05	1.E+05	-8.E+04	-8.E+04	-5.E+05	-8.E+04	-8.E+04	-8.E+04	-5.E+05
Wood, soft, standing	resource	m3	-4.E+04	-9.E+04	-4.E+04	-9.E+04	-9.E+04	-2.E+05	-1.E+05	-9.E+04	-1.E+05	-2.E+05
Non-methane volatile organic compounds (NMVOCs)	air	kg	-2.E+04	-7.E+04	-6.E+03	-7.E+04	-7.E+04	-2.E+05	-7.E+04	-7.E+04	-7.E+04	-2.E+05

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Water, river	resource	m3	8.E+04	5.E+04	8.E+04	5.E+04	3.E+04	-4.E+05	6.E+04	8.E+03	8.E+03	-7.E+05
Gas, mine, off-gas, process, coal mining	resource	Nm3	3.E+04	-5.E+04	3.E+04	-5.E+04	-5.E+04	-2.E+05	-5.E+04	-5.E+04	-5.E+04	-3.E+05
Xenon-135	air	kBq	4.E+04	-4.E+04	6.E+04	-3.E+04	-3.E+04	-2.E+05	-3.E+04	-3.E+04	-3.E+04	-2.E+05
Argon-41	air	kBq	-6.E+03	-3.E+04	-5.E+03	-3.E+04	-3.E+04	-9.E+04	-3.E+04	-3.E+04	-3.E+04	-8.E+04
Radon-220	air	kBq	-1.E+04	-3.E+04	-1.E+04	-3.E+04	-3.E+04	-7.E+04	-3.E+04	-3.E+04	-3.E+04	-7.E+04
Xenon-135m	air	kBq	3.E+04	-2.E+04	4.E+04	-2.E+04	-2.E+04	-1.E+05	-2.E+04	-2.E+04	-2.E+04	-1.E+05
Occupation, water bodies, artificial	resource	m2a	5.E+04	-2.E+04	9.E+04	5.E+03	5.E+03	-2.E+05	9.E+02	-6.E+02	-6.E+03	-2.E+05
Occupation, heterogeneous, agricultural	resource	m2a	-2.E+02	-1.E+03	-2.E+02	-1.E+03	-1.E+03	-3.E+03	-8.E+02	-1.E+03	-8.E+02	-2.E+05
Suspended solids, unspecified	water	kg	2.E+04	1.E+04	2.E+04	2.E+04	9.E+03	-9.E+04	2.E+04	3.E+03	2.E+03	-2.E+05
Iodine-131	air	kBq	-2.E+03	-1.E+04	-2.E+03	-1.E+04	-1.E+04	-4.E+04	-1.E+04	-1.E+04	-1.E+04	-3.E+04
sylvite, 25 % in	resource	kg	6.E+03	1.E+04	6.E+03	1.E+04	1.E+04	2.E+04	-1.E+05	1.E+04	-1.E+05	2.E+04

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
sylvinite, in ground												
Solids, inorganic	water	kg	2.E+03	-9.E+03	3.E+03	-9.E+03	-9.E+03	-3.E+04	-2.E+04	-9.E+03	-2.E+04	-3.E+04
Transformation, from sea and ocean	resource	m^2	3.E+03	3.E+03	4.E+03	4.E+03	9.E+02	-4.E+04	4.E+03	-2.E+03	-2.E+03	-9.E+04
Transformation, to traffic area, road network	resource	m^2	-4.E+03	-8.E+03	-4.E+03	-8.E+03	-8.E+03	-2.E+04	-9.E+03	-8.E+03	-9.E+03	-2.E+04
Particulates, > 10 um	air	kg	4.E+04	7.E+03	4.E+04	8.E+03	8.E+03	-5.E+04	7.E+03	8.E+03	8.E+03	-1.E+05
Barite	water	kg	2.E+03	2.E+03	3.E+03	2.E+03	6.E+02	-3.E+04	2.E+03	-1.E+03	-1.E+03	-5.E+04
Transformation, to dump site	resource	m^2	8.E+03	8.E+03	9.E+03	9.E+03	6.E+03	-4.E+04	9.E+03	3.E+03	3.E+03	-8.E+04
Lead (Pb, ore)	resource	kg	-2.E+03	-5.E+03	-2.E+03	-5.E+03	-5.E+03	-1.E+04	-5.E+03	-5.E+03	-5.E+03	-1.E+04
Xenon-131m	air	kBq	3.E+03	-4.E+03	4.E+03	-3.E+03	-3.E+03	-2.E+04	-3.E+03	-3.E+03	-3.E+03	-2.E+04
Potassium	air	kg	-2.E+03	-4.E+03	-2.E+03	-4.E+03	-4.E+03	-7.E+03	-4.E+03	-4.E+03	-4.E+03	-7.E+03
Phosphorus, 18% in apatite, 12%	resource	kg	8.E+02	1.E+03	8.E+02	1.E+03	1.E+03	2.E+03	-2.E+04	1.E+03	-2.E+04	2.E+03

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
in crude ore, in ground												
Kieserite, 25% in crude ore, in ground	resource	kg	-9.E+02	-2.E+03	-9.E+02	-2.E+03	-2.E+03	-4.E+03	-2.E+03	-2.E+03	-2.E+03	-4.E+03
Potassium-40	water	kBq	-4.E+02	-2.E+03	-4.E+02	-2.E+03	-2.E+03	-4.E+03	-2.E+03	-2.E+03	-2.E+03	-4.E+03
Polonium-210	air	kBq	1.E+03	-1.E+03	1.E+03	-1.E+03	-1.E+03	-5.E+03	-1.E+03	-1.E+03	-1.E+03	-5.E+03
Xenon-133m	air	kBq	-7.E+01	-1.E+03	-1.E+01	-1.E+03	-1.E+03	-3.E+03	-1.E+03	-1.E+03	-1.E+03	-3.E+03
Krypton-87	air	kBq	5.E+02	-1.E+03	7.E+02	-9.E+02	-9.E+02	-4.E+03	-9.E+02	-9.E+02	-9.E+02	-4.E+03
Xenon-138	air	kBq	7.E+03	-5.E+02	1.E+04	1.E+03	1.E+03	-2.E+04	1.E+03	1.E+03	1.E+03	-2.E+04
Krypton-88	air	kBq	7.E+02	-8.E+02	1.E+03	-6.E+02	-6.E+02	-4.E+03	-6.E+02	-6.E+02	-6.E+02	-4.E+03
Fluorine, 4.5% in apatite, 3% in crude ore, in ground	resource	kg	2.E+02	3.E+02	2.E+02	3.E+02	3.E+02	5.E+02	-6.E+03	3.E+02	-6.E+03	5.E+02
Sulphur Dioxide (SO2)	resource	kg	1.E+02	-2.E+02	1.E+02	-2.E+02	-2.E+02	-9.E+02	-3.E+02	-2.E+02	-3.E+02	-6.E+03
Hydrocarbons, aromatic	air	kg	6.E+02	-5.E+02	6.E+02	-5.E+02	-5.E+02	-3.E+03	-5.E+02	-5.E+02	-5.E+02	-3.E+03
Krypton-85m	air	kBq	3.E+03	-5.E+02	4.E+03	1.E+02	1.E+02	-7.E+03	1.E+02	1.E+02	1.E+02	-7.E+03

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Open Loop Output: Mineral Waste (inert)	-	kg	-1.E+02	-2.E+02	-1.E+02	-2.E+02	-2.E+02	-3.E+02	-2.E+02	-2.E+02	-2.E+02	-5.E+03
Ethane	air	kg	2.E+03	2.E+03	1.E+03	1.E+03	1.E+03	-5.E+03	1.E+03	6.E+02	6.E+02	-1.E+04
Lead-210	air	kBq	7.E+02	-5.E+02	7.E+02	-4.E+02	-4.E+02	-3.E+03	-6.E+02	-4.E+02	-5.E+02	-2.E+03
Thorium-232	water	kBq	-2.E+02	-5.E+02	-2.E+02	-5.E+02	-5.E+02	-1.E+03	-5.E+02	-5.E+02	-5.E+02	-1.E+03
Hydrocarbons, aliphatic, unsaturated	air	kg	-2.E+02	-4.E+02	-2.E+02	-4.E+02	-4.E+02	-9.E+02	-4.E+02	-4.E+02	-4.E+02	-9.E+02
Sulphate	air	kg	2.E+02	-2.E+02	2.E+02	-2.E+02	-2.E+02	-1.E+03	-9.E+02	-2.E+02	-9.E+02	-1.E+03
Magnesium	soil	kg	2.E+02	1.E+02	2.E+02	1.E+02	1.E+02	-2.E+01	-3.E+03	1.E+02	-3.E+03	-1.E+02
Oils, biogenic	soil	kg	-2.E+02	-3.E+02	-2.E+02	-3.E+02	-3.E+02	-6.E+02	-4.E+02	-3.E+02	-4.E+02	-6.E+02
Boron	water	kg	-7.E+01	-3.E+02	-6.E+01	-3.E+02	-3.E+02	-7.E+02	-3.E+02	-3.E+02	-3.E+02	-6.E+02
Ozone	air	kg	-1.E+02	-3.E+02	-1.E+02	-3.E+02	-3.E+02	-6.E+02	-3.E+02	-3.E+02	-3.E+02	-6.E+02
Shale, in ground	resource	kg	-1.E+02	-3.E+02	-1.E+02	-3.E+02	-3.E+02	-5.E+02	-3.E+02	-3.E+02	-3.E+02	-5.E+02
Antimony	water	kg	-1.E+02	-3.E+02	-1.E+02	-2.E+02	-2.E+02	-5.E+02	-2.E+02	-2.E+02	-2.E+02	-4.E+02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Copper	soil	kg	-4.E+00	-1.E+01	-4.E+00	-1.E+01	-1.E+01	-2.E+01	-1.E+03	-1.E+01	-1.E+03	-2.E+01
Silicon	soil	kg	-8.E+01	-2.E+02	-8.E+01	-2.E+02	-2.E+02	-5.E+02	-2.E+02	-2.E+02	-2.E+02	-5.E+02
Wood, hard, standing	resource	m3	-3.E+01	-2.E+02	-3.E+01	-2.E+02	-2.E+02	-5.E+02	-8.E+01	-2.E+02	-8.E+01	-3.E+02
Uranium, in ground	resource	kg	5.E+00	-2.E+02	1.E+01	-1.E+02	-1.E+02	-5.E+02	-1.E+02	-1.E+02	-1.E+02	-4.E+02
Oxygen	air	kg	-5.E+01	-9.E+01	-5.E+01	-9.E+01	-9.E+01	-2.E+02	-9.E+01	-9.E+01	-9.E+01	-7.E+02
Sodium	air	kg	-5.E+01	-1.E+02	-5.E+01	-1.E+02	-1.E+02	-3.E+02	-1.E+02	-1.E+02	-1.E+02	-3.E+02
Calcium	air	kg	-3.E+01	-1.E+02	-3.E+01	-1.E+02	-1.E+02	-2.E+02	-1.E+02	-9.E+01	-9.E+01	-2.E+02
Thorium-232	air	kBq	2.E+01	-9.E+01	2.E+01	-9.E+01	-9.E+01	-3.E+02	-9.E+01	-8.E+01	-9.E+01	-3.E+02
Anhydrite, in ground	resource	kg	-4.E+01	-9.E+01	-4.E+01	-9.E+01	-9.E+01	-2.E+02	-9.E+01	-9.E+01	-9.E+01	-2.E+02
Volume occupied, underground deposit	resource	m3	-4.E+01	-8.E+01	-4.E+01	-8.E+01	-8.E+01	-2.E+02	-8.E+01	-8.E+01	-8.E+01	-2.E+02
Potassium	soil	kg	1.E+01	-8.E+01	4.E+01	-6.E+01	-6.E+01	-3.E+02	-6.E+01	-6.E+01	-7.E+01	-3.E+02
Occupation, sea and ocean	resource	m2a	-1.E+01	-3.E+01	-1.E+01	-3.E+01	-3.E+01	-8.E+01	-4.E+01	-3.E+01	-4.E+01	-3.E+02
Manganese	soil	kg	-2.E+01	-5.E+01	-1.E+01	-5.E+01	-5.E+01	-1.E+02	-5.E+01	-5.E+01	-5.E+01	-1.E+02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Butadiene [1,3-Butadiene]	air	kg	-2.E+01	-5.E+01	-2.E+01	-5.E+01	-5.E+01	-9.E+01	-5.E+01	-5.E+01	-5.E+01	-1.E+02
Cumene	water	kg	-2.E+01	-5.E+01	-1.E+01	-4.E+01	-4.E+01	-1.E+02	-4.E+01	-4.E+01	-4.E+01	-1.E+02
Olivine, in ground	resource	kg	-2.E+01	-4.E+01	-2.E+01	-4.E+01	-4.E+01	-9.E+01	-4.E+01	-4.E+01	-4.E+01	-9.E+01
Phosphorus	air	kg	-2.E+01	-4.E+01	-2.E+01	-4.E+01	-4.E+01	-9.E+01	-4.E+01	-4.E+01	-4.E+01	-9.E+01
Formaldehyde	water	kg	-2.E+01	-4.E+01	-2.E+01	-4.E+01	-4.E+01	-8.E+01	-4.E+01	-4.E+01	-4.E+01	-8.E+01
Potassium-40	air	kBq	2.E+02	-2.E+01	2.E+02	-1.E+01	-1.E+01	-5.E+02	1.E+01	-9.E+00	2.E+01	-3.E+02
Ethylene dichloride	water	kg	-2.E+01	-3.E+01	-2.E+01	-3.E+01	-3.E+01	-7.E+01	-3.E+01	-3.E+01	-3.E+01	-7.E+01
Sulfite	water	kg	-1.E+01	-3.E+01	-9.E+00	-3.E+01	-3.E+01	-7.E+01	-3.E+01	-3.E+01	-3.E+01	-7.E+01
Bromine	air	kg	-1.E+01	-3.E+01	-1.E+01	-3.E+01	-3.E+01	-6.E+01	-3.E+01	-3.E+01	-3.E+01	-6.E+01
Ethene	water	kg	-7.E+00	-2.E+01	-7.E+00	-2.E+01	-2.E+01	-5.E+01	-2.E+01	-2.E+01	-2.E+01	-5.E+01
Ethylene diamine	water	kg	-1.E+01	-2.E+01	-1.E+01	-2.E+01	-2.E+01	-4.E+01	-2.E+01	-2.E+01	-2.E+01	-4.E+01
Cumene	air	kg	-6.E+00	-2.E+01	-6.E+00	-2.E+01	-2.E+01	-4.E+01	-2.E+01	-2.E+01	-2.E+01	-4.E+01
m-Xylene	air	kg	-9.E+00	-2.E+01	-9.E+00	-2.E+01	-2.E+01	-4.E+01	-2.E+01	-2.E+01	-2.E+01	-4.E+01
Sulphur	water	kg	1.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	-7.E+02	2.E+02	-7.E+02	5.E+01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Phosphorus	soil	kg	-1.E+00	-2.E+01	2.E+00	-1.E+01	-1.E+01	-5.E+01	-1.E+01	-2.E+01	-2.E+01	-5.E+01
Propene	water	kg	-5.E+00	-2.E+01	-5.E+00	-2.E+01	-2.E+01	-4.E+01	-2.E+01	-2.E+01	-2.E+01	-4.E+01
Ethane, 1,2-dichloro-	air	kg	-7.E+00	-1.E+01	-7.E+00	-1.E+01	-1.E+01	-3.E+01	-1.E+01	-1.E+01	-2.E+01	-3.E+01
Benzene	water	kg	2.E+01	-1.E+01	3.E+01	-4.E+00	-5.E+00	-8.E+01	-5.E+00	-5.E+00	-6.E+00	-9.E+01
Metazachlor	soil	kg	-2.E-01	-6.E-01	-2.E-01	-6.E-01	-6.E-01	-1.E+00	-5.E-01	-6.E-01	-5.E-01	-1.E+02
Chromium VI	soil	kg	-4.E+00	-1.E+01	-4.E+00	-1.E+01	-1.E+01	-2.E+01	-1.E+01	-1.E+01	-1.E+01	-2.E+01
Hypochlorite	water	kg	-3.E+00	-1.E+01	-3.E+00	-1.E+01	-1.E+01	-2.E+01	-1.E+01	-1.E+01	-1.E+01	-2.E+01
Nitrogen - as total N	water	kg	-1.E-01	-5.E-01	-1.E-01	-5.E-01	-5.E-01	-1.E+00	-4.E-01	-5.E-01	-4.E-01	-9.E+01
Iodine	air	kg	-2.E+00	-8.E+00	-2.E+00	-8.E+00	-8.E+00	-2.E+01	-8.E+00	-8.E+00	-8.E+00	-2.E+01
Ethylene diamine	air	kg	-4.E+00	-8.E+00	-4.E+00	-8.E+00	-8.E+00	-2.E+01	-8.E+00	-8.E+00	-8.E+00	-2.E+01
Propionic acid	air	kg	2.E+00	2.E+00	2.E+00	2.E+00	4.E-01	-3.E+01	2.E+00	-1.E+00	-2.E+00	-5.E+01
Monoethanolamine	air	kg	-3.E+00	-6.E+00	-3.E+00	-6.E+00	-6.E+00	-1.E+01	-6.E+00	-6.E+00	-6.E+00	-1.E+01
Selenium	water	kg	-1.E+00	-5.E+00	-1.E+00	-5.E+00	-5.E+00	-1.E+01	-5.E+00	-5.E+00	-5.E+00	-1.E+01
Perlite (SiO2, ore)	resource	kg	3.E-01	9.E-01	3.E-01	9.E-01	9.E-01	2.E+00	1.E+00	9.E-01	1.E+00	-6.E+01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Ilmenite (FeO.TiO2, ore)	resource	kg	3.E-01	9.E-01	3.E-01	9.E-01	9.E-01	2.E+00	1.E+00	9.E-01	1.E+00	-6.E+01
Titanium	soil	kg	-2.E+00	-4.E+00	-2.E+00	-4.E+00	-4.E+00	-9.E+00	-4.E+00	-4.E+00	-4.E+00	-8.E+00
Radioactive species, alpha emitters	water	kBq	9.E+00	1.E+01	9.E+00	1.E+01	1.E+01	2.E+01	-7.E+01	1.E+01	-7.E+01	2.E+01
Sulphur hexafluoride	air	kg	-2.E+00	-4.E+00	-2.E+00	-4.E+00	-4.E+00	-9.E+00	-4.E+00	-4.E+00	-4.E+00	-9.E+00
Scandium	water	kg	-4.E-01	-4.E+00	-3.E-01	-4.E+00	-4.E+00	-1.E+01	-4.E+00	-4.E+00	-4.E+00	-1.E+01
Aldehydes, unspecified	air	kg	2.E-01	-2.E+00	3.E-01	-2.E+00	-2.E+00	-5.E+00	-2.E+00	-2.E+00	-2.E+00	-2.E+01
Tungsten	water	kg	-5.E-01	-3.E+00	-5.E-01	-3.E+00	-3.E+00	-8.E+00	-3.E+00	-3.E+00	-3.E+00	-7.E+00
Manganese	air	kg	1.E+01	-3.E-01	1.E+01	-3.E-01	-3.E-01	-3.E+01	1.E-01	2.E-01	6.E-01	-2.E+01
Beryllium	water	kg	-1.E-01	-1.E+00	-1.E-01	-1.E+00	-1.E+00	-4.E+00	-1.E+00	-1.E+00	-1.E+00	-3.E+00
Cyanide	air	kg	3.E+00	-1.E+00	3.E+00	-1.E+00	-1.E+00	-9.E+00	-1.E+00	-9.E-01	-8.E-01	-5.E+00
Granite, in ground	resource	kg	-5.E-01	-1.E+00	-5.E-01	-1.E+00	-1.E+00	-2.E+00	-1.E+00	-1.E+00	-1.E+00	-2.E+00
Glutaraldehyde	water	kg	3.E-01	2.E-01	3.E-01	3.E-01	7.E-02	-3.E+00	3.E-01	-2.E-01	-2.E-01	-7.E+00
Kaolin (Al_2O_3.2SiO	resource	kg	4.E-02	1.E-01	4.E-02	1.E-01	1.E-01	3.E-01	2.E-01	1.E-01	2.E-01	-9.E+00

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
2.2H2O, ore)												
Open Loop Output: Non-toxic Chemicals (unspecified)	-	kg	-6.E-02	-9.E-02	-6.E-02	-9.E-02	-9.E-02	-1.E-01	-9.E-02	-9.E-02	-9.E-02	-6.E+00
Nitrogen	air	kg	-1.E-01	-3.E-01	-1.E-01	-3.E-01	-3.E-01	-6.E-01	-3.E-01	-3.E-01	-3.E-01	-2.E+00
Dichromate	water	kg	-1.E-01	-3.E-01	-1.E-01	-3.E-01	-3.E-01	-6.E-01	-3.E-01	-3.E-01	-3.E-01	-6.E-01
Ethylene oxide [1,2-Epoxyethane]	air	kg	-9.E-02	-3.E-01	-9.E-02	-3.E-01	-3.E-01	-6.E-01	-3.E-01	-3.E-01	-3.E-01	-6.E-01
t-Butyl methyl ether	air	kg	-1.E-01	-2.E-01	-1.E-01	-2.E-01	-2.E-01	-5.E-01	-4.E-01	-2.E-01	-4.E-01	-5.E-01
Transformation, to sea and ocean	resource	m^2	8.E-02	1.E-01	8.E-02	1.E-01	2.E-02	-1.E+00	1.E-01	-4.E-02	-4.E-02	-2.E+00
Sodium chlorate	air	kg	-8.E-02	-2.E-01	-8.E-02	-2.E-01	-2.E-01	-4.E-01	-2.E-01	-2.E-01	-2.E-01	-4.E-01
Vanadium	soil	kg	-5.E-02	-1.E-01	-5.E-02	-1.E-01	-1.E-01	-2.E-01	-1.E-01	-1.E-01	-1.E-01	-2.E-01
Methiocarb	soil	kg	-2.E-03	-6.E-03	-2.E-03	-6.E-03	-6.E-03	-1.E-02	-5.E-03	-6.E-03	-5.E-03	-1.E+00
Rutile, in ground	resource	kg	6.E-03	2.E-02	6.E-03	2.E-02	2.E-02	5.E-02	2.E-02	2.E-02	2.E-02	-1.E+00

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Phosphorus Pentoxide (P2O5)	water	kg	8.E-03	2.E-02	8.E-03	2.E-02	2.E-02	4.E-02	2.E-02	2.E-02	2.E-02	-1.E+00
Isocyanic acid	air	kg	5.E-02	-4.E-02	5.E-02	-4.E-02	-4.E-02	-2.E-01	-7.E-02	-4.E-02	-7.E-02	-2.E-01
Cobalt	soil	kg	-2.E-02	-5.E-02	-2.E-02	-5.E-02	-5.E-02	-1.E-01	-5.E-02	-5.E-02	-5.E-02	-1.E-01
Cesium-137	air	kBq	3.E-02	-2.E-02	4.E-02	-1.E-02	-1.E-02	-1.E-01	-2.E-02	-1.E-02	-2.E-02	-3.E-01
Cesium-134	air	kBq	-5.E-03	-2.E-02	-4.E-03	-2.E-02	-2.E-02	-5.E-02	-2.E-02	-2.E-02	-2.E-02	-2.E-01
Promethium-147	air	kBq	-5.E-03	-1.E-02	-5.E-03	-1.E-02	-1.E-02	-3.E-02	-2.E-02	-1.E-02	-2.E-02	-1.E-01
Ammonium carbonate	air	kg	-5.E-03	-2.E-02	-5.E-03	-2.E-02	-2.E-02	-4.E-02	-1.E-02	-2.E-02	-1.E-02	-3.E-02
Molybdenum	soil	kg	-5.E-03	-1.E-02	-5.E-03	-1.E-02	-1.E-02	-2.E-02	-1.E-02	-1.E-02	-1.E-02	-2.E-02
Cerium-144	air	kBq	-1.E-03	-4.E-03	-1.E-03	-4.E-03	-4.E-03	-1.E-02	-5.E-03	-4.E-03	-5.E-03	-4.E-02
Ethylene oxide	water	kg	-3.E-03	-7.E-03	-3.E-03	-7.E-03	-7.E-03	-2.E-02	-8.E-03	-7.E-03	-8.E-03	-8.E-03
Occupation, urban, continuously built	resource	m2a	2.E-04	6.E-04	2.E-04	6.E-04	6.E-04	1.E-03	7.E-04	6.E-04	7.E-04	-4.E-02
Kerosene	air	kg	-8.E-04	-2.E-03	-8.E-04	-2.E-03	-2.E-03	-3.E-03	-2.E-03	-2.E-03	-2.E-03	-6.E-03
Ferromanganese, in ground	resource	kg	1.E-04	3.E-04	1.E-04	3.E-04	3.E-04	5.E-04	3.E-04	3.E-04	3.E-04	-2.E-02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Curium alpha	air	kBq	-2.E-04	-7.E-04	-2.E-04	-7.E-04	-7.E-04	-2.E-03	-7.E-04	-7.E-04	-7.E-04	-6.E-03
Silver	soil	kg	-4.E-04	-9.E-04	-4.E-04	-9.E-04	-9.E-04	-2.E-03	-1.E-03	-9.E-04	-1.E-03	-2.E-03
Americium-241	air	kBq	-2.E-04	-5.E-04	-2.E-04	-5.E-04	-5.E-04	-1.E-03	-6.E-04	-5.E-04	-6.E-04	-4.E-03
Dinoseb	soil	kg	-4.E-04	-8.E-04	-4.E-04	-8.E-04	-8.E-04	-2.E-03	-9.E-04	-8.E-04	-9.E-04	-2.E-03
Pt, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	resource	kg	5.E-04	-5.E-04	7.E-04	-4.E-04	-4.E-04	-3.E-03	-4.E-04	-4.E-04	-4.E-04	-3.E-03
Hydrogen	water	kg	-1.E-04	-3.E-04	-1.E-04	-3.E-04	-3.E-04	-8.E-04	-4.E-04	-3.E-04	-4.E-04	-3.E-03
Acenaphthene	air	kg	-2.E-05	-5.E-05	-2.E-05	-5.E-05	-1.E-04	-2.E-03	-5.E-05	-2.E-04	-2.E-04	-3.E-03
Acenaphthylene	water	kg	2.E-04	8.E-06	2.E-04	5.E-05	5.E-05	-3.E-04	3.E-05	4.E-05	2.E-05	-3.E-03
Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	air	kg	-9.E-05	-2.E-04	-3.E-05	-2.E-04	-2.E-04	-6.E-04	-2.E-04	-2.E-04	-2.E-04	-7.E-04

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Pt, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	resource	kg	1.E-04	-1.E-04	2.E-04	-1.E-04	-1.E-04	-7.E-04	-1.E-04	-1.E-04	-1.E-04	-8.E-04
Nitrogen	soil	kg	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05	-2.E-03
Diatomite, in ground	resource	kg	-4.E-05	-8.E-05	-4.E-05	-8.E-05	-8.E-05	-2.E-04	-9.E-05	-8.E-05	-9.E-05	-2.E-04
Atrazine	soil	kg	-1.E-05	-4.E-05	-1.E-05	-4.E-05	-4.E-05	-8.E-05	-4.E-05	-4.E-05	-4.E-05	-5.E-05
Transformation, to urban, continuously built	resource	m^2	2.E-06	7.E-06	2.E-06	7.E-06	7.E-06	2.E-05	8.E-06	7.E-06	8.E-06	-4.E-04
Platinum	air	kg	-9.E-07	-4.E-06	-8.E-07	-4.E-06	-4.E-06	-1.E-05	-4.E-06	-4.E-06	-4.E-06	-1.E-05
Polychlorinated biphenyls (PCBs) - total as WHO TEQ	air	kg	-5.E-07	-1.E-06	-5.E-07	-1.E-06	-1.E-06	-2.E-06	-1.E-06	-1.E-06	-1.E-06	-7.E-06

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Long chain (C18-28) chlorinated paraffins, LCCPs	water	kg	-5.E-07	-1.E-06	-5.E-07	-1.E-06	-1.E-06	-2.E-06	-1.E-06	-1.E-06	-1.E-06	-2.E-06
Chlorophenol	air	kg	-2.E-07	-4.E-07	-2.E-07	-4.E-07	-4.E-07	-8.E-07	-5.E-07	-4.E-07	-5.E-07	-3.E-06
Phthalate, dibutyl-	water	kg	-4.E-08	-1.E-07	-4.E-08	-1.E-07	-1.E-07	-3.E-07	-1.E-07	-1.E-07	-1.E-07	-3.E-06
Ethane, 1,1,1-trichloro-, HCFC-140	water	kg	-6.E-08	-1.E-07	-6.E-08	-1.E-07	-1.E-07	-2.E-07	-1.E-07	-1.E-07	-1.E-07	-1.E-06
Ethene, tetrachloro-	water	kg	4.E-08	2.E-08	4.E-08	2.E-08	2.E-08	-2.E-08	2.E-08	2.E-08	2.E-08	-1.E-06
Cobalt-57	air	kBq	-2.E-08	-5.E-08	-2.E-08	-5.E-08	-5.E-08	-1.E-07	-5.E-08	-5.E-08	-5.E-08	-4.E-07
Curium-244	air	kBq	-9.E-09	-3.E-08	-9.E-09	-3.E-08	-3.E-08	-6.E-08	-3.E-08	-3.E-08	-3.E-08	-2.E-07
Dioxins and furans- as WHO TEQ	air	kg	1.E-08	2.E-09	1.E-08	2.E-09	2.E-09	-1.E-08	1.E-09	2.E-09	1.E-09	-1.E-07
Trichlorobenzene - all isomers	water	kg	9.E-11	6.E-10	9.E-11	6.E-10	6.E-10	2.E-09	8.E-10	6.E-10	8.E-10	-8.E-08
Curium-242	air	kBq	-1.E-09	-3.E-09	-1.E-09	-3.E-09	-3.E-09	-6.E-09	-3.E-09	-3.E-09	-3.E-09	-2.E-08
Ethane, hexachloro-	water	kg	1.E-10	5.E-11	1.E-10	5.E-11	5.E-11	-1.E-10	6.E-11	5.E-11	6.E-11	-4.E-09

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Cerium, in ground	resource	kg	-1.E-10	-1.E-10	-1.E-10	-1.E-10	-1.E-10	-1.E-10	-1.E-10	-1.E-10	-1.E-10	-5.E-11
Lanthanum, in crude ore, in ground	resource	kg	-5.E-12	-3.E-12	-5.E-12	-4.E-12	-4.E-12	-4.E-13	-5.E-12	-4.E-12	-5.E-12	6.E-13
Neodymium, in ground	resource	kg	9.E-11	8.E-11	8.E-11	8.E-11	8.E-11	7.E-11	7.E-11	7.E-11	6.E-11	3.E-11
Methyl bromide [Bromomethane]	air	kg	6.E-10	1.E-09	6.E-10	1.E-09	1.E-09	2.E-09	1.E-09	1.E-09	1.E-09	2.E-09
Phosphorus - as total P	water	kg	-3.E-09	-6.E-10	-3.E-09	-6.E-10	-6.E-10	4.E-09	-2.E-09	-6.E-10	-2.E-09	5.E-07
Thallium	soil	kg	2.E-06	2.E-06	2.E-06	2.E-06	2.E-06	2.E-06	2.E-06	2.E-06	2.E-06	2.E-06
Phosphorus hydride	air	kg	1.E-06	2.E-06	1.E-06	2.E-06	2.E-06	3.E-06	2.E-06	2.E-06	2.E-06	9.E-06
Dioxins and furans- as ITEQ	air	kg	1.E-08	-4.E-09	1.E-08	-4.E-09	-4.E-09	-3.E-08	-7.E-09	4.E-07	4.E-07	3.E-05
Herbicides, unspecified	water	kg	2.E-06	3.E-06	2.E-06	3.E-06	3.E-06	4.E-06	2.E-06	3.E-06	2.E-06	1.E-05
Methylamine [Methanamine]	air	kg	6.E-06	9.E-06	6.E-06	9.E-06	9.E-06	2.E-05	9.E-06	9.E-06	9.E-06	3.E-05
Paraffins	air	kg	1.E-05	1.E-05	2.E-05	2.E-05	2.E-05	1.E-05	2.E-05	1.E-05	1.E-05	8.E-06
Plutonium-238	air	kBq	3.E-05	2.E-05	3.E-05	2.E-05	2.E-05	-6.E-06	2.E-05	2.E-05	2.E-05	8.E-06

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Selenium	soil	kg	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05	2.E-05
Chlorinated Matter (unspecified, as Cl)	air	kg	3.E-05	4.E-05	3.E-05	4.E-05	4.E-05	6.E-05	3.E-05	4.E-05	3.E-05	2.E-04
Acetone	water	kg	3.E-05	6.E-05	4.E-05	6.E-05	6.E-05	1.E-04	6.E-05	6.E-05	6.E-05	1.E-04
Antimony	soil	kg	5.E-05	8.E-05	5.E-05	8.E-05	8.E-05	1.E-04	8.E-05	9.E-05	9.E-05	2.E-04
Edetic Acid (EDTA, C10H16N2O8)	water	kg	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04
Tungsten	air	kg	5.E-05	9.E-05	5.E-05	9.E-05	9.E-05	2.E-04	1.E-04	9.E-05	1.E-04	2.E-04
Alcohol (unspecified)	air	kg	6.E-05	9.E-05	6.E-05	9.E-05	9.E-05	2.E-04	8.E-05	9.E-05	8.E-05	3.E-04
Antimony-124	air	kBq	3.E-04	1.E-04	4.E-04	2.E-04	2.E-04	-3.E-04	2.E-04	2.E-04	2.E-04	-3.E-04
Stibnite, in ground	resource	kg	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	1.E-04	1.E-04	1.E-04	2.E-04
o-Xylene	water	kg	8.E-05	1.E-04	8.E-05	1.E-04	1.E-04	2.E-04	1.E-04	1.E-04	1.E-04	3.E-04
Open Loop Output: Highly Radioactive	-	kg	3.E-04	3.E-04	3.E-04	3.E-04	3.E-04	2.E-04	3.E-04	3.E-04	3.E-04	-7.E-04

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Waste (Class C)												
Rhenium, in crude ore, in ground	resource	kg	3.E-04	2.E-04	3.E-04	3.E-04	3.E-04	2.E-04	3.E-04	3.E-04	3.E-04	2.E-05
Rh, Rh 2.0E-5%, Pt 2.5E-4%, Pd 7.3E-4%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	resource	kg	3.E-04	3.E-04	3.E-04	3.E-04	3.E-04	2.E-04	3.E-04	3.E-04	3.E-04	7.E-05
Chloroform [Trichloromethane]	water	kg	2.E-04	3.E-04	2.E-04	3.E-04	3.E-04	4.E-04	2.E-04	3.E-04	2.E-04	1.E-03
Teflubenzuron	soil	kg	4.E-04	4.E-04	5.E-04	4.E-04	4.E-04	3.E-04	4.E-04	4.E-04	4.E-04	2.E-04
Cobalt-58	air	kBq	4.E-03	1.E-03	6.E-03	2.E-03	2.E-03	-6.E-03	2.E-03	2.E-03	2.E-03	-1.E-02
Morpholine (C4H9NO)	water	kg	5.E-04	5.E-04	5.E-04	5.E-04	5.E-04	5.E-04	5.E-04	5.E-04	5.E-04	5.E-04
Rh, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%,	resource	kg	9.E-04	8.E-04	1.E-03	9.E-04	9.E-04	6.E-04	9.E-04	9.E-04	9.E-04	2.E-04

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Cu 5.2E-2% in ore, in ground												
Chromium-51	air	kBq	3.E-03	1.E-03	4.E-03	2.E-03	2.E-03	-3.E-03	2.E-03	2.E-03	2.E-03	-4.E-03
Antimony-125	air	kBq	3.E-03	1.E-03	4.E-03	2.E-03	2.E-03	-3.E-03	2.E-03	2.E-03	2.E-03	-3.E-03
Ethene, chloro-	water	kg	4.E-03	3.E-03	4.E-03	3.E-03	3.E-03	4.E-04	3.E-03	3.E-03	3.E-03	-4.E-04
Cadmium-109	water	kBq	1.E-03	2.E-03	1.E-03	2.E-03	2.E-03	5.E-03	2.E-03	2.E-03	2.E-03	5.E-03
Methane, trifluoro-, HFC-23	air	kg	2.E-03	3.E-03	2.E-03	3.E-03	3.E-03	5.E-03	3.E-03	3.E-03	3.E-03	6.E-03
Acenaphthene	water	kg	3.E-03	3.E-03	4.E-03	4.E-03	4.E-03	3.E-03	4.E-03	4.E-03	4.E-03	1.E-03
Lanthanum	air	kg	3.E-03	3.E-03	3.E-03	3.E-03	3.E-03	3.E-03	3.E-03	3.E-03	3.E-03	3.E-03
Benzene, pentachloro-	air	kg	2.E-03	3.E-03	2.E-03	3.E-03	3.E-03	6.E-03	3.E-03	3.E-03	3.E-03	6.E-03
Ethyl, disulfide	air	kg	2.E-03	4.E-03	2.E-03	4.E-03	4.E-03	8.E-03	4.E-03	4.E-03	4.E-03	8.E-03
Benzaldehyde	air	kg	4.E-03	5.E-03	6.E-03	6.E-03	6.E-03	6.E-03	5.E-03	5.E-03	5.E-03	4.E-03
Tin	soil	kg	2.E-03	4.E-03	2.E-03	4.E-03	4.E-03	6.E-03	4.E-03	4.E-03	4.E-03	2.E-02
Metribuzin	soil	kg	7.E-03	6.E-03	7.E-03	6.E-03	6.E-03	4.E-03	6.E-03	6.E-03	6.E-03	3.E-03

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Ethane thiol	air	kg	1.E-02	8.E-03	6.E-03	6.E-03	6.E-03	4.E-03	6.E-03	6.E-03	5.E-03	3.E-03
Iron-59	air	kBq	3.E-03	7.E-03	3.E-03	7.E-03	7.E-03	1.E-02	8.E-03	7.E-03	8.E-03	2.E-02
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	air	kg	8.E-03	8.E-03	8.E-03	8.E-03	8.E-03	8.E-03	9.E-03	9.E-03	9.E-03	7.E-03
Silicon tetrafluoride	air	kg	6.E-03	8.E-03	7.E-03	9.E-03	8.E-03	1.E-02	9.E-03	8.E-03	8.E-03	1.E-02
Methane, bromochlorodifluoro-, Halon 1211	air	kg	1.E-01	2.E-01	1.E-01	2.E-01	1.E-01	-3.E-01	2.E-01	1.E-01	1.E-01	-8.E-01
Scandium	air	kg	3.E-02	2.E-02	3.E-02	2.E-02	2.E-02	-7.E-03	2.E-02	2.E-02	2.E-02	-3.E-02
Acrolein	air	kg	8.E-03	8.E-03	1.E-02	9.E-03	9.E-03	6.E-03	9.E-03	1.E-02	1.E-02	4.E-02
Tellurium-132	water	kBq	2.E-02	1.E-02	2.E-02	1.E-02	1.E-02	4.E-03	1.E-02	1.E-02	1.E-02	5.E-03
Cobalt-60	air	kBq	4.E-02	2.E-02	5.E-02	2.E-02	2.E-02	-4.E-02	2.E-02	2.E-02	2.E-02	-4.E-02
Pd, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2%	resource	kg	1.E-02	1.E-02	2.E-02	2.E-02	2.E-02	1.E-02	1.E-02	1.E-02	1.E-02	1.E-02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
in ore, in ground												
Propanal	air	kg	1.E-02	2.E-02	1.E-02	2.E-02	2.E-02	2.E-02	2.E-02	2.E-02	2.E-02	2.E-02
Zirconium	air	kg	1.E-01	7.E-02	1.E-01	7.E-02	7.E-02	-7.E-02	7.E-02	7.E-02	7.E-02	-4.E-01
Cesium-136	water	kBq	4.E-02	2.E-02	5.E-02	3.E-02	3.E-02	-3.E-02	3.E-02	3.E-02	3.E-02	-3.E-02
Tellurium-123m	air	kBq	8.E-03	2.E-02	8.E-03	2.E-02	2.E-02	3.E-02	2.E-02	2.E-02	2.E-02	4.E-02
Cerium-141	air	kBq	5.E-02	2.E-02	7.E-02	3.E-02	3.E-02	-4.E-02	3.E-02	3.E-02	3.E-02	-4.E-02
Open Loop Output: Low Radioactive Waste (Class A)	-	kg	3.E-02	2.E-02	3.E-02	2.E-02	2.E-02	2.E-02	2.E-02	2.E-02	2.E-02	-1.E-02
Orbencarb	soil	kg	4.E-02	3.E-02	4.E-02	3.E-02	3.E-02	2.E-02	3.E-02	3.E-02	3.E-02	2.E-02
Pd, Pd 7.3E-4%, Pt 2.5E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	resource	kg	3.E-02	3.E-02	4.E-02	4.E-02	4.E-02	3.E-02	4.E-02	4.E-02	3.E-02	3.E-02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Volume occupied, final repository for radioactive waste	resource	m3	6.E-02	4.E-02	6.E-02	4.E-02	4.E-02	-6.E-03	4.E-02	4.E-02	4.E-02	3.E-02
Iron-59	water	kBq	1.E-01	5.E-02	1.E-01	6.E-02	6.E-02	-6.E-02	6.E-02	6.E-02	6.E-02	-7.E-02
Ethane, 2,2-dichloro-1,1,1-tri-fluoro-, HCFC-123	air	kg	2.E-02	4.E-02	2.E-02	4.E-02	4.E-02	9.E-02	5.E-02	4.E-02	5.E-02	9.E-02
Metaldehyde	soil	kg	3.E-02	5.E-02	3.E-02	5.E-02	5.E-02	7.E-02	5.E-02	5.E-02	5.E-02	7.E-02
Thorium	air	kg	5.E-02	5.E-02	5.E-02	5.E-02	5.E-02	6.E-02	5.E-02	5.E-02	5.E-02	3.E-02
Yttrium-90	water	kBq	2.E-02	5.E-02	2.E-02	5.E-02	5.E-02	9.E-02	5.E-02	5.E-02	5.E-02	1.E-01
Fenpiclonil	soil	kg	4.E-02	5.E-02	4.E-02	5.E-02	5.E-02	8.E-02	5.E-02	5.E-02	5.E-02	8.E-02
Fungicides, unspecified	water	kg	3.E-02	5.E-02	3.E-02	5.E-02	5.E-02	1.E-01	5.E-02	5.E-02	5.E-02	1.E-01
Sulphuric Acid (H_2SO_4)	air	kg	7.E-02	6.E-02	7.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	5.E-02
Chromate (CrO4--)	water	kg	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Hydrogen cyanide	air	kg	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02	6.E-02
Pirimicarb	soil	kg	5.E-02	7.E-02	5.E-02	7.E-02	7.E-02	1.E-01	7.E-02	7.E-02	7.E-02	1.E-01
Uranium	air	kg	7.E-02	8.E-02	7.E-02	8.E-02	8.E-02	1.E-01	8.E-02	8.E-02	8.E-02	1.E-01
Barium-140	air	kBq	2.E-01	9.E-02	3.E-01	1.E-01	1.E-01	-2.E-01	1.E-01	1.E-01	1.E-01	-2.E-01
Polycyclic Aromatic Hydrocarbon (Borneff Six)	air	kg	9.E-02	9.E-02	9.E-02	9.E-02	9.E-02	8.E-02	9.E-02	9.E-02	9.E-02	6.E-02
Napropamide	soil	kg	6.E-02	8.E-02	6.E-02	8.E-02	8.E-02	1.E-01	8.E-02	8.E-02	8.E-02	1.E-01
Carbon tetrachloride [Tetrachloromethane]	air	kg	6.E-02	7.E-02	7.E-02	7.E-02	7.E-02	7.E-02	7.E-02	7.E-02	7.E-02	3.E-01
Beryllium	air	kg	9.E-02	1.E-01	9.E-02	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01
Lanthanum-140	air	kBq	6.E-02	9.E-02	6.E-02	9.E-02	9.E-02	1.E-01	1.E-01	9.E-02	1.E-01	2.E-01
Silver	air	kg	5.E-02	9.E-02	5.E-02	9.E-02	9.E-02	2.E-01	9.E-02	9.E-02	9.E-02	2.E-01
Cobalt, in ground	resource	kg	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	7.E-02	1.E-01	1.E-01	1.E-01	2.E-02
Hexachlorobenzene	air	kg	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Fluosilicic acid	air	kg	2.E-01	2.E-02	2.E-01	3.E-02	3.E-02	-3.E-01	3.E-01	6.E-02	3.E-01	3.E-01
Thallium	air	kg	4.E-02	3.E-02	4.E-02	3.E-02	3.E-02	1.E-02	4.E-02	4.E-02	4.E-02	8.E-01
Pentachlorophenol	air	kg	-4.E-02	-1.E-01	-4.E-02	-1.E-01	-1.E-01	-3.E-01	-1.E-01	7.E-03	2.E-02	2.E+00
Molybdenum-99	water	kBq	2.E-01	1.E-01	3.E-01	1.E-01	1.E-01	-1.E-01	2.E-01	1.E-01	2.E-01	-1.E-01
Ethyl, chloride	air	kg	5.E-02	1.E-01	5.E-02	1.E-01	1.E-01	2.E-01	1.E-01	1.E-01	1.E-01	2.E-01
Styrene	air	kg	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	7.E-02	1.E-01	2.E-01	2.E-01	6.E-02
Ethane, hexafluoro-, HFC-116	air	kg	2.E-01	4.E-02	2.E-01	5.E-02	4.E-02	-2.E-01	2.E-01	8.E-02	3.E-01	4.E-01
Chlorothalonil	soil	kg	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	8.E-02	1.E-01	1.E-01	1.E-01	7.E-02
Polychlorinated biphenyls	air	kg	2.E-01	1.E-01	2.E-01	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	4.E-03
Volume occupied, final repository for low-active radioactive waste	resource	m3	2.E-01	1.E-01	2.E-01	1.E-01	1.E-01	-3.E-02	2.E-01	2.E-01	2.E-01	9.E-02
Cerium-141	water	kBq	3.E-01	1.E-01	3.E-01	2.E-01	2.E-01	-7.E-02	2.E-01	2.E-01	2.E-01	-7.E-02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Ruthenium-103	air	kBq	7.E-02	1.E-01	7.E-02	1.E-01	1.E-01	3.E-01	1.E-01	1.E-01	1.E-01	3.E-01
Mancozeb	soil	kg	2.E-01	2.E-01	2.E-01	2.E-01	2.E-01	1.E-01	2.E-01	2.E-01	2.E-01	9.E-02
Butene	water	kg	8.E-02	1.E-01	8.E-02	1.E-01	1.E-01	3.E-01	1.E-01	1.E-01	1.E-01	3.E-01
Ruthenium-103	water	kBq	1.E-01	1.E-01	1.E-01	2.E-01	2.E-01	2.E-01	2.E-01	2.E-01	2.E-01	3.E-01
Mercaptans	air	kg	2.E-01	2.E-01	1.E-01	2.E-01	2.E-01	3.E-01	2.E-01	2.E-01	2.E-01	1.E-01
Solvent (unspecified)	water	kg	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01	2.E-01	1.E-01	1.E-01	1.E-01	6.E-01
Fluosilicic acid	water	kg	3.E-01	4.E-02	3.E-01	5.E-02	5.E-02	-5.E-01	5.E-01	1.E-01	5.E-01	6.E-01
Tebutam	soil	kg	1.E-01	2.E-01	1.E-01	2.E-01	2.E-01	3.E-01	2.E-01	2.E-01	2.E-01	3.E-01
Niobium-95	air	kBq	1.E-01	2.E-01	1.E-01	2.E-01	2.E-01	4.E-01	2.E-01	2.E-01	2.E-01	5.E-01
Carbetamide	soil	kg	2.E-01	3.E-01	2.E-01	3.E-01	3.E-01	4.E-01	2.E-01	3.E-01	2.E-01	4.E-01
Propylene oxide	air	kg	2.E-01	3.E-01	2.E-01	3.E-01	3.E-01	4.E-01	3.E-01	3.E-01	3.E-01	4.E-01
Phosphorus Pentoxide (P2O5)	air	kg	1.E-01	2.E-01	1.E-01	2.E-01	2.E-01	5.E-01	3.E-01	2.E-01	3.E-01	6.E-01
Zirconia, as baddeleyite, in ground	resource	kg	2.E-01	2.E-01	2.E-01	2.E-01	2.E-01	3.E-01	2.E-01	2.E-01	2.E-01	9.E-01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Benzene, chloro-	water	kg	2.E-01	2.E-01	2.E-01	3.E-01	3.E-01	4.E-01	2.E-01	3.E-01	2.E-01	8.E-01
Methane, bromotrifluoro-, Halon 1301	air	kg	3.E-01	3.E-01	4.E-01	4.E-01	4.E-01	3.E-01	3.E-01	3.E-01	3.E-01	1.E-01
Lanthanum-140	water	kBq	6.E-01	3.E-01	8.E-01	4.E-01	4.E-01	-3.E-01	4.E-01	4.E-01	4.E-01	-3.E-01
Feldspar, in ground	resource	kg	3.E-02	-9.E-02	3.E-02	-9.E-02	-9.E-02	-3.E-01	-1.E-01	-9.E-02	-1.E-01	4.E+00
Fluorides (F-)	air	kg	4.E-01	4.E-01	4.E-01	4.E-01	4.E-01	4.E-01	4.E-01	4.E-01	4.E-01	4.E-01
Tributyltin compounds	water	kg	9.E-01	5.E-01	1.E+00	6.E-01	6.E-01	-2.E-01	6.E-01	6.E-01	6.E-01	-2.E+00
Chlorinated solvents, unspecified	water	kg	4.E-01	4.E-01	4.E-01	4.E-01	4.E-01	3.E-01	4.E-01	4.E-01	4.E-01	1.E+00
Selenium	air	kg	8.E-01	4.E-01	8.E-01	5.E-01	5.E-01	-2.E-01	5.E-01	5.E-01	5.E-01	2.E-01
Antimony-122	water	kBq	3.E-01	4.E-01	4.E-01	5.E-01	5.E-01	7.E-01	5.E-01	5.E-01	5.E-01	8.E-01
Cesium	water	kg	5.E-01	5.E-01	7.E-01	6.E-01	6.E-01	5.E-01	6.E-01	6.E-01	6.E-01	2.E-01
Silver, ion	water	kg	5.E-01	5.E-01	6.E-01	6.E-01	6.E-01	6.E-01	6.E-01	6.E-01	6.E-01	4.E-01
Ethane, 1,1-difluoro-, HFC-152a	air	kg	3.E-01	6.E-01	3.E-01	6.E-01	6.E-01	1.E+00	6.E-01	6.E-01	6.E-01	1.E+00
Benzo(a)pyrene	air	kg	3.E-01	1.E-01	3.E-01	1.E-01	1.E-01	-3.E-01	1.E-01	4.E-01	5.E-01	5.E+00

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Iodine-135	air	kBq	7.E-01	6.E-01	7.E-01	6.E-01	6.E-01	5.E-01	7.E-01	7.E-01	7.E-01	7.E-01
Mercury	soil	kg	7.E-03	1.E-02	7.E-03	1.E-02	1.E-02	1.E-02	3.E+00	1.E-02	3.E+00	2.E-02
Propylene oxide	water	kg	5.E-01	6.E-01	5.E-01	6.E-01	6.E-01	9.E-01	6.E-01	6.E-01	6.E-01	9.E-01
Thallium	water	kg	3.E-01	3.E-01	3.E-01	3.E-01	3.E-01	3.E-01	3.E-01	3.E-01	3.E-01	4.E+00
Barium-140	water	kBq	8.E-01	6.E-01	9.E-01	7.E-01	7.E-01	3.E-01	8.E-01	7.E-01	8.E-01	4.E-01
Cadmium, ion	water	kg	4.E+00	2.E+00	4.E+00	2.E+00	2.E+00	-3.E+00	1.E+00	2.E+00	1.E+00	-6.E+00
Bentazone	soil	kg	5.E-01	7.E-01	5.E-01	7.E-01	7.E-01	1.E+00	7.E-01	7.E-01	7.E-01	1.E+00
Vermiculite, in ground	resource	kg	1.E+00	8.E-01	1.E+00	9.E-01	9.E-01	3.E-01	1.E+00	9.E-01	1.E+00	-6.E-01
Hydroxide	water	kg	4.E-01	7.E-01	4.E-01	7.E-01	7.E-01	1.E+00	7.E-01	7.E-01	7.E-01	2.E+00
Halogenated hydrocarbons, chlorinated	air	kg	8.E-01	8.E-01	8.E-01	9.E-01	9.E-01	9.E-01	9.E-01	9.E-01	9.E-01	8.E-01
Methane, tetrafluoro-, FC-14	air	kg	1.E+00	2.E-01	1.E+00	2.E-01	2.E-01	-2.E+00	2.E+00	5.E-01	2.E+00	3.E+00
Nonylphenols	water	kg	3.E+00	2.E+00	5.E-01	5.E-01	5.E-01	5.E-01	5.E-01	5.E-01	5.E-01	2.E-01
Sodium dichromate	air	kg	4.E-01	8.E-01	4.E-01	8.E-01	8.E-01	2.E+00	8.E-01	8.E-01	8.E-01	2.E+00

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Cobalt-57	water	kBq	1.E+00	9.E-01	2.E+00	1.E+00	1.E+00	-2.E-01	1.E+00	1.E+00	1.E+00	-2.E-01
Strontium-89	air	kBq	4.E-01	9.E-01	4.E-01	9.E-01	9.E-01	2.E+00	1.E+00	9.E-01	1.E+00	2.E+00
Halogenated Hydrocarbons (unspecified)	air	kg	1.E+00	1.E+00	1.E+00	1.E+00	1.E+00	1.E+00	1.E+00	1.E+00	1.E+00	1.E+00
Molybdenum	air	kg	7.E-01	1.E+00	7.E-01	1.E+00	1.E+00	2.E+00	1.E+00	1.E+00	1.E+00	2.E+00
Trichlorobenzene - all isomers	air	kg	2.E+00	1.E+00	1.E+00	1.E+00	1.E+00	6.E-01	1.E+00	1.E+00	1.E+00	4.E-01
Antimony	air	kg	3.E-01	4.E-01	3.E-01	4.E-01	4.E-01	5.E-01	4.E-01	4.E-01	4.E-01	9.E+00
Naphthalene	water	kg	5.E+00	4.E+00	5.E-01	5.E-01	5.E-01	6.E-01	5.E-01	5.E-01	5.E-01	4.E-01
Cadmium	soil	kg	3.E-02	3.E-02	3.E-02	3.E-02	3.E-02	2.E-02	6.E+00	3.E-02	6.E+00	3.E-02
Aclonifen	soil	kg	1.E+00	1.E+00	1.E+00	1.E+00	1.E+00	2.E+00	1.E+00	1.E+00	1.E+00	2.E+00
Biphenyl	water	kg	3.E+00	2.E+00	1.E+00	1.E+00	1.E+00	1.E+00	1.E+00	1.E+00	1.E+00	6.E-01
Open Loop Output: Treatment Waste	-	kg	3.E+01	3.E+01	3.E+01	3.E+01	3.E+01	4.E+01	3.E+01	3.E+01	3.E+01	-3.E+02
Silver, 0.01% in	resource	kg	9.E-01	1.E+00	9.E-01	1.E+00	1.E+00	3.E+00	1.E+00	1.E+00	1.E+00	4.E+00

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
crude ore, in ground												
Cadmium	air	kg	1.E+00	1.E+00	1.E+00	2.E+00	2.E+00	2.E+00	1.E+00	2.E+00	1.E+00	3.E+00
Cypermethrin	soil	kg	8.E-01	2.E+00	8.E-01	2.E+00	2.E+00	3.E+00	2.E+00	2.E+00	2.E+00	3.E+00
Ethane, 1,1,1-trichloro-, HCFC-140	air	kg	8.E-01	2.E+00	8.E-01	2.E+00	2.E+00	3.E+00	2.E+00	2.E+00	2.E+00	3.E+00
Barium	air	kg	3.E+00	2.E+00	3.E+00	2.E+00	2.E+00	4.E-01	2.E+00	2.E+00	2.E+00	-6.E-01
Technetium -99m	water	kBq	5.E+00	2.E+00	6.E+00	3.E+00	3.E+00	-4.E+00	3.E+00	3.E+00	3.E+00	-4.E+00
Ulexite, in ground	resource	kg	2.E+00	2.E+00	2.E+00	2.E+00	2.E+00	1.E+00	2.E+00	2.E+00	2.E+00	3.E+00
Chlorine	water	kg	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	2.E+00	3.E+00	3.E+00	3.E+00	-4.E+00
Cinnabar, in ground	resource	kg	7.E-01	1.E+00	7.E-01	1.E+00	1.E+00	3.E+00	1.E+00	1.E+00	1.E+00	1.E+01
Iodine-133	water	kBq	1.E+00	2.E+00	1.E+00	2.E+00	2.E+00	3.E+00	2.E+00	2.E+00	2.E+00	4.E+00
Iodine-133	air	kBq	1.E+00	2.E+00	2.E+00	2.E+00	2.E+00	4.E+00	2.E+00	2.E+00	2.E+00	4.E+00
m-Xylene	water	kg	2.E+00	2.E+00	2.E+00	2.E+00	2.E+00	2.E+00	2.E+00	2.E+00	2.E+00	2.E+00
Colemanite, in ground	resource	kg	7.E+00	2.E+00	8.E+00	2.E+00	2.E+00	-1.E+01	2.E-01	2.E+00	1.E-01	2.E+01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Ethene, trichloro-	water	kg	1.E+00	2.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	1.E+00
Strontium	soil	kg	3.E+00	2.E+00	3.E+00	3.E+00	3.E+00	2.E+00	3.E+00	3.E+00	3.E+00	1.E+00
Open Loop Output: Intermediate Radioactive Waste (Class B)	-	kg	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00
Strontium	air	kg	4.E+00	3.E+00	4.E+00	3.E+00	3.E+00	8.E-01	3.E+00	3.E+00	3.E+00	-8.E-03
Triethylene glycol	water	kg	2.E+00	3.E+00	2.E+00	3.E+00	3.E+00	4.E+00	3.E+00	3.E+00	3.E+00	4.E+00
Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore, in ground	resource	kg	5.E+00	3.E+00	5.E+00	3.E+00	3.E+00	-2.E+00	3.E+00	3.E+00	3.E+00	6.E+00
Methanol	water	kg	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	4.E+00
2,4-D	soil	kg	2.E+00	3.E+00	2.E+00	3.E+00	3.E+00	6.E+00	3.E+00	3.E+00	3.E+00	6.E+00
Organic tin compounds - as total Sn	water	kg	3.E+00	3.E+00	4.E+00	4.E+00	4.E+00	3.E+00	4.E+00	4.E+00	4.E+00	1.E+00

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Actinides, radioactive, unspecified	air	kBq	3.E+00	3.E+00	3.E+00	3.E+00	3.E+00	4.E+00	3.E+00	3.E+00	4.E+00	5.E+00
Phenol	water	kg	5.E+01	1.E+01	5.E+01	1.E+01	1.E+01	-5.E+01	1.E+01	1.E+01	1.E+01	-8.E+01
Mecoprop	water	kg	2.E+01	2.E+01	5.E-01	6.E-01	6.E-01	8.E-01	6.E-01	6.E-01	6.E-01	6.E-01
Boron	soil	kg	2.E+00	5.E-01	2.E+00	1.E+00	1.E+00	-2.E+00	2.E+01	9.E-01	2.E+01	-3.E+00
Titanium	air	kg	7.E+00	5.E+00	7.E+00	5.E+00	5.E+00	2.E+00	6.E+00	6.E+00	6.E+00	-3.E+00
Fluoride	soil	kg	1.E+01	5.E+00	1.E+01	7.E+00	7.E+00	-5.E+00	7.E+00	7.E+00	7.E+00	-9.E+00
Diethyl sulphate	air	kg	9.E+00	7.E+00	5.E+00	5.E+00	5.E+00	3.E+00	5.E+00	5.E+00	4.E+00	3.E+00
Rubidium	water	kg	5.E+00	5.E+00	7.E+00	6.E+00	6.E+00	5.E+00	6.E+00	6.E+00	6.E+00	2.E+00
Neptunium-237	water	kBq	3.E+00	5.E+00	3.E+00	5.E+00	5.E+00	1.E+01	5.E+00	5.E+00	5.E+00	1.E+01
Neptunium-237	air	kBq	3.E+00	5.E+00	3.E+00	5.E+00	5.E+00	1.E+01	5.E+00	5.E+00	5.E+00	1.E+01
Tin	air	kg	6.E+00	6.E+00	6.E+00	6.E+00	6.E+00	6.E+00	6.E+00	6.E+00	6.E+00	7.E+00
Transformation, to traffic area, rail network	resource	m^2	2.E+01	1.E+01	2.E+01	1.E+01	1.E+01	-9.E+00	1.E+01	1.E+01	1.E+01	-3.E+01
Hydrocarbons,	water	kg	6.E+00	6.E+00	8.E+00	7.E+00	7.E+00	5.E+00	7.E+00	7.E+00	7.E+00	3.E+00

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
aliphatic, unsaturated												
Dichloromethane	water	kg	6.E+00	6.E+00	8.E+00	7.E+00	7.E+00	6.E+00	7.E+00	7.E+00	7.E+00	3.E+00
Alkylacetates	air	kg	4.E+00	6.E+00	4.E+00	6.E+00	6.E+00	9.E+00	5.E+00	6.E+00	5.E+00	2.E+01
Mercury	water	kg	7.E+00	7.E+00	8.E+00	7.E+00	7.E+00	6.E+00	7.E+00	7.E+00	7.E+00	6.E+00
Magnesium, 0.13% in water	resource	kg	4.E+00	7.E+00	4.E+00	7.E+00	7.E+00	1.E+01	6.E+00	7.E+00	6.E+00	1.E+01
Arsenic	air	kg	7.E+00	7.E+00	7.E+00	7.E+00	7.E+00	5.E+00	7.E+00	7.E+00	7.E+00	1.E+01
Lithium	water	kg	4.E+00	6.E+00	4.E+00	7.E+00	7.E+00	1.E+01	6.E+00	7.E+00	6.E+00	1.E+01
para-Dichlorobenzene [1,4-Dichlorobenzene]	air	kg	1.E+01	1.E+01	8.E+00	7.E+00	7.E+00	4.E+00	7.E+00	7.E+00	7.E+00	3.E+00
Ethyl toluene - all isomers	air	kg	1.E+01	1.E+01	9.E+00	8.E+00	8.E+00	5.E+00	8.E+00	8.E+00	7.E+00	4.E+00
Metals (unspecified)	water	kg	9.E+00	9.E+00	9.E+00	9.E+00	9.E+00	9.E+00	1.E+01	1.E+01	1.E+01	-3.E+00
Ethane, 2-chloro-1,1,1,2-	air	kg	2.E+01	1.E+01	9.E+00	9.E+00	9.E+00	5.E+00	9.E+00	9.E+00	9.E+00	3.E+00

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
tetra-fluoro-, HCFC-124												
Methyl chlorophenoxy acetic acid (MCPA)	water	kg	4.E+01	3.E+01	3.E+00	3.E+00	3.E+00	4.E+00	3.E+00	3.E+00	3.E+00	2.E+00
Sulfide	water	kg	1.E+01	9.E+00	1.E+01	9.E+00	9.E+00	8.E+00	9.E+00	9.E+00	9.E+00	8.E+00
Fluorine	air	kg	1.E+01	9.E+00	1.E+01	9.E+00	9.E+00	2.E+00	1.E+01	1.E+01	1.E+01	8.E+00
Acetonitrile [Ethane nitrile]	air	kg	5.E+00	9.E+00	5.E+00	9.E+00	9.E+00	2.E+01	9.E+00	9.E+00	9.E+00	2.E+01
Chromium VI	air	kg	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01
PAH, polycyclic aromatic hydrocarbons	water	kg	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	9.E+00
Hydrocarbons, aliphatic, alkanes, cyclic	air	kg	9.E+00	1.E+01	9.E+00	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01
Phosphorus	water	kg	2.E+01	1.E+01	2.E+01	1.E+01	1.E+01	7.E+00	1.E+01	1.E+01	1.E+01	-9.E+00
Linuron	soil	kg	8.E+00	1.E+01	8.E+00	1.E+01	1.E+01	2.E+01	1.E+01	1.E+01	1.E+01	2.E+01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Transformation, to urban, discontinuously built	resource	m^2	6.E+00	1.E+01	6.E+00	1.E+01	1.E+01	2.E+01	1.E+01	1.E+01	1.E+01	2.E+01
Nitrate	air	kg	5.E+00	1.E+01	5.E+00	1.E+01	1.E+01	2.E+01	1.E+01	1.E+01	1.E+01	2.E+01
Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore, in ground	resource	kg	2.E+01	1.E+01	2.E+01	1.E+01	1.E+01	-7.E+00	1.E+01	1.E+01	1.E+01	2.E+01
Insecticides, unspecified	water	kg	5.E+00	1.E+01	5.E+00	1.E+01	1.E+01	2.E+01	1.E+01	1.E+01	1.E+01	2.E+01
Tellurium-123m	water	kBq	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	2.E+01
Mercury	air	kg	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	2.E+01
Aniline [Benzeneamine]	water	kg	3.E+01	2.E+01	9.E+00	9.E+00	9.E+00	9.E+00	9.E+00	9.E+00	8.E+00	4.E+00
Phenol	air	kg	6.E+00	1.E+01	6.E+00	1.E+01	1.E+01	2.E+01	1.E+01	1.E+01	1.E+01	3.E+01
Cobalt	air	kg	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	2.E+01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Metals (unspecified)	air	kg	1.E+01	1.E+01	1.E+01	1.E+01	1.E+01	2.E+01	1.E+01	1.E+01	1.E+01	2.E+01
Ethylbenzene	water	kg	1.E+01	1.E+01	2.E+01	2.E+01	2.E+01	1.E+01	2.E+01	2.E+01	1.E+01	6.E+00
Sodium-24	water	kBq	8.E+00	1.E+01	8.E+00	1.E+01	1.E+01	2.E+01	1.E+01	1.E+01	1.E+01	3.E+01
Ethane, 1,1-dichloro-	air	kg	3.E+01	2.E+01	2.E+01	1.E+01	1.E+01	8.E+00	1.E+01	1.E+01	1.E+01	5.E+00
Nitrite	water	kg	8.E+00	1.E+01	8.E+00	1.E+01	1.E+01	3.E+01	2.E+01	1.E+01	1.E+01	3.E+01
Butene - all isomers	air	kg	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	1.E+01	2.E+01	2.E+01	2.E+01	7.E+00
Transformation, to pasture and meadow	resource	m^2	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	3.E+01	-1.E+01	2.E+01	-1.E+01	4.E+01
PAH, polycyclic aromatic hydrocarbons	air	kg	4.E+01	3.E+01	3.E+01	2.E+01	2.E+01	-4.E+00	2.E+01	2.E+01	2.E+01	-3.E+01
Carbonyl, sulfide	air	kg	3.E+01	2.E+01	2.E+01	2.E+01	2.E+01	1.E+01	2.E+01	2.E+01	2.E+01	9.E+00
Methyl chloride [Chloromethane]	air	kg	3.E+01	3.E+01	2.E+01	2.E+01	2.E+01	1.E+01	2.E+01	2.E+01	2.E+01	7.E+00
Chlorine	air	kg	2.E+01	2.E+00	2.E+01	3.E+00	2.E+00	-3.E+01	3.E+00	2.E+00	3.E+00	2.E+02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
tert-Butyl methyl ether (MTBE)	water	kg	3.E+01	3.E+01	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	9.E+00
Helium	air	kg	2.E+01	2.E+01	3.E+01	3.E+01	3.E+01	2.E+01	3.E+01	3.E+01	2.E+01	2.E+00
Tin, 79% in cassiterite, 0.1% in crude ore, in ground	resource	kg	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	3.E+01
Strontium-89	water	kBq	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	3.E+01	2.E+01	2.E+01	2.E+01	3.E+01
Iodine-131	water	kBq	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	3.E+01	2.E+01	2.E+01	2.E+01	4.E+01
Glyphosate	soil	kg	1.E+01	2.E+01	1.E+01	2.E+01	2.E+01	4.E+01	2.E+01	2.E+01	2.E+01	4.E+01
Formaldehyde [Methanal]	air	kg	4.E+01	4.E+01	4.E+01	4.E+01	4.E+01	-1.E+01	4.E+01	3.E+01	3.E+01	-3.E+01
Chrysotile, in ground	resource	kg	9.E+00	2.E+01	9.E+00	2.E+01	2.E+01	3.E+01	2.E+01	2.E+01	2.E+01	1.E+02
Arsenic, ion	water	kg	4.E+01	3.E+01	4.E+01	3.E+01	3.E+01	8.E+00	3.E+01	3.E+01	3.E+01	1.E+01
Ethane, 1,1,2-trichloro-	air	kg	5.E+01	3.E+01	3.E+01	3.E+01	3.E+01	1.E+01	3.E+01	3.E+01	2.E+01	8.E+00
Niobium-95	water	kBq	2.E+01	2.E+01	2.E+01	2.E+01	2.E+01	4.E+01	3.E+01	3.E+01	3.E+01	4.E+01
Transformation, from	resource	m^2	3.E+01	3.E+01	3.E+01	3.E+01	3.E+01	2.E+01	3.E+01	3.E+01	3.E+01	2.E+01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
industrial area												
Zinc-65	air	kBq	1.E+01	3.E+01	1.E+01	3.E+01	3.E+01	5.E+01	3.E+01	3.E+01	3.E+01	6.E+01
Ethane, 1,1-dichloro-1,1,2,2-tetrafluoro-	air	kg	5.E+01	4.E+01	3.E+01	3.E+01	3.E+01	2.E+01	3.E+01	3.E+01	3.E+01	8.E+00
Arsenic	soil	kg	9.E-02	8.E-02	1.E-01	1.E-01	1.E-01	5.E-02	2.E+02	9.E-02	2.E+02	1.E-02
Metamorphous rock, graphite containing, in ground	resource	kg	2.E+01	3.E+01	2.E+01	3.E+01	3.E+01	3.E+01	3.E+01	3.E+01	4.E+01	7.E+01
Cadmium	water	kg	7.E+01	6.E+01	3.E+01	3.E+01	3.E+01	2.E+01	3.E+01	3.E+01	3.E+01	3.E+01
Copper	air	kg	4.E+01	3.E+01	4.E+01	3.E+01	3.E+01	2.E+01	3.E+01	3.E+01	4.E+01	4.E+01
Molybdenum	water	kg	-2.E+00	-1.E+01	-1.E+00	-1.E+01	-1.E+01	-3.E+01	-1.E+01	2.E+01	3.E+01	4.E+02
Nickel	air	kg	4.E+01	4.E+01	4.E+01	4.E+01	4.E+01	3.E+01	4.E+01	4.E+01	4.E+01	4.E+01
Zinc-65	water	kBq	3.E+01	3.E+01	4.E+01	4.E+01	4.E+01	3.E+01	4.E+01	4.E+01	4.E+01	4.E+01
Chloroform [Trichloromethane]	air	kg	8.E+01	6.E+01	5.E+01	4.E+01	4.E+01	2.E+01	4.E+01	4.E+01	4.E+01	1.E+01
Lead	air	kg	7.E+01	5.E+01	7.E+01	5.E+01	5.E+01	2.E+01	5.E+01	5.E+01	5.E+01	-2.E+01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Aerosols, radioactive, unspecified	air	kBq	6.E+01	4.E+01	6.E+01	5.E+01	5.E+01	2.E+01	5.E+01	5.E+01	5.E+01	5.E+01
Chlorides (Cl-)	air	kg							2.E+02		2.E+02	
Iodide	water	kg	5.E+01	5.E+01	7.E+01	6.E+01	6.E+01	4.E+01	6.E+01	6.E+01	6.E+01	2.E+01
Krypton-89	air	kBq	4.E+02	7.E+01	5.E+02	1.E+02	1.E+02	-5.E+02	1.E+02	1.E+02	1.E+02	-5.E+02
Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground	resource	kg	7.E+00	3.E+00	7.E+00	3.E+00	3.E+00	-6.E+00	9.E-01	3.E+00	1.E+00	5.E+02
Thorium-234	air	kBq	4.E+01	5.E+01	4.E+01	5.E+01	5.E+01	6.E+01	6.E+01	5.E+01	6.E+01	9.E+01
Acetaldehyde [Ethanal]	air	kg	6.E+01	6.E+01	4.E+01	5.E+01	5.E+01	7.E+01	5.E+01	5.E+01	5.E+01	7.E+01
Nickel	soil	kg	-9.E-02	-2.E-01	-9.E-02	-2.E-01	-2.E-01	-4.E-01	3.E+02	-2.E-01	3.E+02	-4.E-01
Xylene - all isomers [Dimethylbenzene]	water	kg	6.E+01	6.E+01	7.E+01	7.E+01	7.E+01	5.E+01	7.E+01	7.E+01	6.E+01	3.E+01
Tin, ion	water	kg	3.E+01	6.E+01	3.E+01	6.E+01	6.E+01	1.E+02	6.E+01	6.E+01	6.E+01	1.E+02
Vanadium	air	kg	4.E+01	5.E+01	4.E+01	6.E+01	6.E+01	8.E+01	5.E+01	6.E+01	5.E+01	1.E+02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Acrylonitrile [2-Propenenitrile]	air	kg	1.E+02	8.E+01	6.E+01	6.E+01	6.E+01	4.E+01	6.E+01	6.E+01	5.E+01	3.E+01
Raw Materials (unspecified)	resource	kg	6.E+01	6.E+01	6.E+01	6.E+01	6.E+01	7.E+01	6.E+01	6.E+01	6.E+01	1.E+02
Hydrogen sulfide	water	kg	5.E+01	8.E+01	5.E+01	8.E+01	8.E+01	1.E+02	8.E+01	7.E+01	7.E+01	4.E+01
Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore, in ground	resource	kg	4.E+01	3.E+01	4.E+01	3.E+01	3.E+01	-4.E+00	3.E+01	5.E+01	5.E+01	4.E+02
Toluene	water	kg	8.E+01	7.E+01	8.E+01	8.E+01	8.E+01	6.E+01	7.E+01	7.E+01	7.E+01	3.E+01
Hydrocarbons, aliphatic, alkanes, unspecified	water	kg	7.E+01	7.E+01	9.E+01	8.E+01	8.E+01	6.E+01	8.E+01	8.E+01	7.E+01	3.E+01
Phosphate Rock (in ground)	resource	kg	8.E+01	8.E+01	8.E+01	8.E+01	8.E+01	8.E+01	8.E+01	8.E+01	8.E+01	8.E+01
Propan-2-ol	air	kg	1.E+02	1.E+02	8.E+01	8.E+01	8.E+01	5.E+01	7.E+01	7.E+01	7.E+01	4.E+01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Magnesium	air	kg	9.E+01	8.E+01	9.E+01	8.E+01	8.E+01	7.E+01	8.E+01	8.E+01	8.E+01	3.E+01
Chromium	soil	kg	1.E+00	1.E+00	2.E+00	1.E+00	1.E+00	8.E-01	4.E+02	1.E+00	4.E+02	3.E-01
Metolachlor	soil	kg	6.E+01	8.E+01	6.E+01	8.E+01	8.E+01	1.E+02	8.E+01	8.E+01	8.E+01	1.E+02
Boron	air	kg	7.E+01	8.E+01	8.E+01	8.E+01	8.E+01	8.E+01	8.E+01	8.E+01	8.E+01	1.E+02
Methanol	air	kg	5.E+01	7.E+01	5.E+01	7.E+01	7.E+01	1.E+02	7.E+01	7.E+01	7.E+01	2.E+02
Ketone (unspecified)	air	kg	1.E+02	1.E+02	8.E+01	8.E+01	8.E+01	6.E+01	8.E+01	8.E+01	7.E+01	6.E+01
Ethylene, 1,1-dichloro-	air	kg	2.E+02	1.E+02	9.E+01	8.E+01	8.E+01	5.E+01	8.E+01	8.E+01	8.E+01	3.E+01
Pyrite, in ground	resource	kg	9.E+01	9.E+01	9.E+01	9.E+01	9.E+01	9.E+01	9.E+01	9.E+01	9.E+01	9.E+01
Americium-241	water	kBq	4.E+01	8.E+01	4.E+01	8.E+01	8.E+01	2.E+02	8.E+01	8.E+01	8.E+01	2.E+02
Wood, unspecified, standing	resource	m3	4.E+01	9.E+01	4.E+01	9.E+01	9.E+01	2.E+02	9.E+01	9.E+01	9.E+01	2.E+02
Sodium formate	water	kg	5.E+01	9.E+01	5.E+01	9.E+01	9.E+01	2.E+02	9.E+01	9.E+01	9.E+01	2.E+02
Acetone	air	kg	1.E+02	1.E+02	8.E+01	1.E+02	1.E+02	1.E+02	9.E+01	1.E+02	9.E+01	1.E+02
Curium alpha	water	kBq	5.E+01	9.E+01	5.E+01	9.E+01	9.E+01	2.E+02	1.E+02	9.E+01	1.E+02	2.E+02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Ethane, 1-chloro-1,1-difluoro-, HCFC-142	air	kg	2.E+02	1.E+02	1.E+02	1.E+02	1.E+02	6.E+01	1.E+02	1.E+02	1.E+02	3.E+01
Methane, chloro-fluoro-, HCFC-31	air	kg	2.E+02	1.E+02	1.E+02	1.E+02	1.E+02	6.E+01	1.E+02	1.E+02	1.E+02	3.E+01
Ethyne	air	kg	6.E+01	1.E+02	6.E+01	1.E+02	1.E+02	2.E+02	1.E+02	1.E+02	1.E+02	2.E+02
Acetic acid	air	kg	1.E+02	2.E+02	1.E+02	2.E+02	2.E+02	8.E+01	2.E+02	1.E+02	1.E+02	-1.E+02
Methane, chlorotrifluoro-, CFC-13	air	kg	2.E+02	1.E+02	1.E+02	1.E+02	1.E+02	6.E+01	1.E+02	1.E+02	1.E+02	3.E+01
Sodium formate	air	kg	5.E+01	1.E+02	5.E+01	1.E+02	1.E+02	2.E+02	1.E+02	1.E+02	1.E+02	2.E+02
Calcium	soil	kg	6.E+02	1.E+02	9.E+02	3.E+02	3.E+02	-8.E+02	3.E+02	3.E+02	3.E+02	-1.E+03
Heptane	air	kg	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	5.E+01
Trimethylbenzene - all isomers	air	kg	2.E+02	2.E+02	1.E+02	1.E+02	1.E+02	7.E+01	1.E+02	1.E+02	1.E+02	5.E+01
Dimethyl disulphide	air	kg	2.E+02	2.E+02	1.E+02	1.E+02	1.E+02	7.E+01	1.E+02	1.E+02	1.E+02	6.E+01
Bromate	water	kg	4.E+01	8.E+01	4.E+01	8.E+01	8.E+01	1.E+02	8.E+01	8.E+01	8.E+01	6.E+02
Barium	soil	kg	1.E+02	1.E+02	2.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	6.E+01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Sulphur	soil	kg	1.E+02	1.E+02	2.E+02	2.E+02	2.E+02	8.E+01	1.E+02	1.E+02	1.E+02	3.E+01
Antimony-124	water	kBq	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	2.E+02	1.E+02	1.E+02	1.E+02	2.E+02
Antimony-125	water	kBq	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	2.E+02	1.E+02	1.E+02	1.E+02	2.E+02
Tetrachloroethane [1,1,2,2-Tetrachloroethane]	air	kg	2.E+02	2.E+02	1.E+02	1.E+02	1.E+02	7.E+01	1.E+02	1.E+02	1.E+02	4.E+01
Chromium-51	water	kBq	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	2.E+02
Propylene [1-Propene]	air	kg	9.E+01	1.E+02	1.E+02	1.E+02	1.E+02	2.E+02	1.E+02	1.E+02	1.E+02	2.E+02
Pentene - all isomers	air	kg	3.E+02	2.E+02	1.E+02	1.E+02	1.E+02	9.E+01	1.E+02	1.E+02	1.E+02	7.E+01
Xenon-137	air	kBq	1.E+03	2.E+02	1.E+03	4.E+02	4.E+02	-1.E+03	4.E+02	4.E+02	4.E+02	-1.E+03
Terpenes	air	kg	3.E+02	2.E+02	2.E+02	2.E+02	2.E+02	1.E+02	1.E+02	1.E+02	1.E+02	9.E+01
Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground	resource	kg	3.E+02	2.E+02	3.E+02	2.E+02	2.E+02	-1.E+02	1.E+02	2.E+02	1.E+02	3.E+02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Bromine	water	kg	3.E+02	2.E+02	4.E+02	2.E+02	2.E+02	-9.E+01	2.E+02	2.E+02	2.E+02	-2.E+02
Methane, dichlorofluoro-, HCFC-21	air	kg	3.E+02	2.E+02	2.E+02	2.E+02	2.E+02	9.E+01	2.E+02	2.E+02	2.E+02	5.E+01
Zirconium-95	water	kBq	8.E+01	2.E+02	8.E+01	2.E+02	2.E+02	3.E+02	2.E+02	2.E+02	2.E+02	4.E+02
Actinides, radioactive, unspecified	water	kBq	3.E+02	2.E+02	3.E+02	2.E+02	2.E+02	-7.E+01	2.E+02	2.E+02	2.E+02	1.E+02
Benzene, ethyl-	air	kg	3.E+02	2.E+02	2.E+02	2.E+02	2.E+02	1.E+02	2.E+02	2.E+02	2.E+02	8.E+01
Zirconium-95	air	kBq	8.E+01	2.E+02	8.E+01	2.E+02	2.E+02	3.E+02	2.E+02	2.E+02	2.E+02	4.E+02
Cyanide	water	kg	3.E+02	2.E+02	3.E+02	2.E+02	2.E+02	1.E+02	2.E+02	2.E+02	2.E+02	5.E+01
Aluminum	soil	kg	2.E+02	2.E+02	3.E+02	2.E+02	2.E+02	1.E+02	2.E+02	2.E+02	2.E+02	6.E+00
Occupation, pasture and meadow	resource	m2a	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	3.E+02	4.E+02	4.E+02	4.E+02	-1.E+03
Trichloroethylene	air	kg	4.E+02	3.E+02	2.E+02	2.E+02	2.E+02	1.E+02	2.E+02	2.E+02	2.E+02	7.E+01
Propane	air	kg	9.E+02	9.E+02	1.E+03	1.E+03	9.E+02	-1.E+03	1.E+03	7.E+02	7.E+02	-4.E+03
Zinc	air	kg	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02
Arsenic	water	kg	4.E+02	3.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	1.E+02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Pentane	air	kg	1.E+03	9.E+02	1.E+03	1.E+03	9.E+02	-1.E+03	1.E+03	7.E+02	7.E+02	-4.E+03
Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore, in ground	resource	kg	4.E+02	2.E+02	4.E+02	2.E+02	2.E+02	-1.E+02	2.E+02	2.E+02	2.E+02	4.E+02
Dichloromethane	air	kg	4.E+02	3.E+02	3.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	8.E+01
Silver-110	air	kBq	1.E+02	2.E+02	1.E+02	2.E+02	2.E+02	4.E+02	2.E+02	2.E+02	2.E+02	5.E+02
Hydrogen peroxide	water	kg	1.E+02	2.E+02	1.E+02	2.E+02	2.E+02	5.E+02	2.E+02	2.E+02	2.E+02	5.E+02
Hydrocarbons, aromatic	water	kg	3.E+02	3.E+02	4.E+02	3.E+02	3.E+02	2.E+02	3.E+02	3.E+02	3.E+02	4.E+01
Fluorine, 4.5% in apatite, 1% in crude ore, in ground	resource	kg	2.E+02	3.E+02	2.E+02	3.E+02	3.E+02	4.E+02	3.E+02	3.E+02	3.E+02	4.E+02
Ethanol	air	kg	5.E+02	4.E+02	3.E+02	3.E+02	3.E+02	2.E+02	3.E+02	3.E+02	3.E+02	1.E+02
VOC, volatile organic compounds,	water	kg	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	9.E+02	2.E+02	9.E+02	8.E+01

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
unspecified origin												
Iron	air	kg	3.E+02	3.E+02	3.E+02	3.E+02	3.E+02	4.E+02	3.E+02	3.E+02	3.E+02	4.E+02
Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	air	kg	6.E+02	4.E+02	4.E+02	3.E+02	3.E+02	2.E+02	3.E+02	3.E+02	3.E+02	9.E+01
Di(2-ethylhexyl)phthalate (DEHP)	water	kg	3.E+02	3.E+02	4.E+02	4.E+02	4.E+02	3.E+02	4.E+02	4.E+02	4.E+02	1.E+02
Copper	water	kg	5.E+02	4.E+02	3.E+02	2.E+02	2.E+02	2.E+02	2.E+02	3.E+02	3.E+02	9.E+02
Plutonium-alpha	water	kBq	2.E+02	3.E+02	2.E+02	3.E+02	3.E+02	6.E+02	3.E+02	3.E+02	3.E+02	7.E+02
Plutonium-alpha	air	kBq	2.E+02	3.E+02	2.E+02	3.E+02	3.E+02	6.E+02	3.E+02	3.E+02	3.E+02	7.E+02
Ethylene dichloride [1,2-Dichloroethane]	air	kg	6.E+02	5.E+02	4.E+02	4.E+02	4.E+02	2.E+02	4.E+02	3.E+02	3.E+02	1.E+02
Chromium	water	kg	5.E+02	4.E+02	3.E+02	3.E+02	3.E+02	3.E+02	3.E+02	3.E+02	3.E+02	3.E+02
Strontium	water	kg	8.E+02	4.E+02	1.E+03	6.E+02	6.E+02	-4.E+02	5.E+02	5.E+02	5.E+02	-9.E+02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Hexane	air	kg	8.E+02	9.E+02	7.E+02	8.E+02	7.E+02	-4.E+02	8.E+02	6.E+02	6.E+02	-2.E+03
Ammonium, ion	water	kg	2.E+02	3.E+02	2.E+02	3.E+02	3.E+02	4.E+02	3.E+02	3.E+02	3.E+02	1.E+03
Pentachlorophenol	water	kg	5.E+02	5.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	3.E+02	2.E+02
Thorium-234	water	kBq	5.E+02	4.E+02	5.E+02	4.E+02	4.E+02	6.E+01	4.E+02	4.E+02	4.E+02	3.E+02
Protactinium-234	air	kBq	2.E+02	4.E+02	2.E+02	4.E+02	4.E+02	7.E+02	4.E+02	4.E+02	4.E+02	8.E+02
Vanadium, ion	water	kg	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	5.E+02
Transformation, to heterogeneous, agricultural	resource	m^2	5.E+02	4.E+02	6.E+02	5.E+02	5.E+02	3.E+02	5.E+02	5.E+02	5.E+02	4.E+01
Lead	soil	kg	1.E-01	4.E-02	1.E-01	5.E-02	5.E-02	-7.E-02	2.E+03	4.E-02	2.E+03	-4.E-02
Chromium	air	kg	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	5.E+02
Acidity, unspecified	water	kg	3.E+02	4.E+02	3.E+02	4.E+02	4.E+02	6.E+02	4.E+02	4.E+02	4.E+02	6.E+02
Nickel	water	kg	6.E+02	5.E+02	5.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02	4.E+02
Fluoride	water	kg	6.E+02	4.E+02	6.E+02	4.E+02	4.E+02	1.E+02	4.E+02	5.E+02	4.E+02	1.E+03
Acetic acid	water	kg	6.E+02	6.E+02	6.E+02	6.E+02	6.E+02	6.E+02	6.E+02	6.E+02	6.E+02	6.E+02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Occupation, urban, discontinuously built	resource	m2a	3.E+02	5.E+02	3.E+02	5.E+02	5.E+02	9.E+02	5.E+02	5.E+02	5.E+02	9.E+02
Methane, trichlorofluoro-, CFC-11	air	kg	1.E+03	8.E+02	6.E+02	6.E+02	6.E+02	3.E+02	6.E+02	6.E+02	6.E+02	2.E+02
Silver-110	water	kBq	5.E+02	5.E+02	6.E+02	6.E+02	6.E+02	6.E+02	6.E+02	6.E+02	6.E+02	7.E+02
Borax, in ground	resource	kg	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	2.E+02	4.E+02	5.E+02	4.E+03
Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	air	kg	1.E+03	9.E+02	7.E+02	6.E+02	6.E+02	3.E+02	6.E+02	6.E+02	6.E+02	2.E+02
Iron	soil	kg	1.E+03	7.E+02	1.E+03	8.E+02	8.E+02	1.E+02	8.E+02	8.E+02	8.E+02	-7.E+02
Toluene	air	kg	1.E+03	9.E+02	7.E+02	7.E+02	7.E+02	4.E+02	7.E+02	7.E+02	6.E+02	3.E+02
Barium	water	kg	5.E+02	4.E+02	7.E+02	5.E+02	5.E+02	2.E+02	5.E+02	7.E+02	7.E+02	2.E+03
Uranium-235	air	kBq	3.E+02	6.E+02	3.E+02	6.E+02	6.E+02	1.E+03	7.E+02	6.E+02	7.E+02	1.E+03
Zinc	soil	kg	7.E+00	4.E+00	8.E+00	5.E+00	5.E+00	-3.E+00	4.E+03	5.E+00	4.E+03	-5.E+00
Protactinium-234	water	kBq	7.E+02	7.E+02	7.E+02	7.E+02	7.E+02	7.E+02	8.E+02	7.E+02	8.E+02	1.E+03
Lead	water	kg	7.E+02	7.E+02	7.E+02	7.E+02	7.E+02	8.E+02	7.E+02	8.E+02	7.E+02	1.E+03

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Ethylene [Ethene]	air	kg	7.E+02	8.E+02	6.E+02	8.E+02	8.E+02	1.E+03	8.E+02	8.E+02	7.E+02	7.E+02
Tetrachloroethylene	air	kg	1.E+03	1.E+03	8.E+02	8.E+02	8.E+02	4.E+02	7.E+02	7.E+02	7.E+02	2.E+02
Transformation, to water courses, artificial	resource	m^2	5.E+02	7.E+02	5.E+02	7.E+02	7.E+02	1.E+03	7.E+02	7.E+02	8.E+02	1.E+03
Water, lake	resource	m3	1.E+03	9.E+02	1.E+03	1.E+03	1.E+03	3.E+02	1.E+03	1.E+03	1.E+03	-7.E+02
Carbon	soil	kg	8.E+02	7.E+02	1.E+03	9.E+02	9.E+02	7.E+02	9.E+02	8.E+02	8.E+02	5.E+02
Transformation, from dump site	resource	m^2	6.E+02	8.E+02	6.E+02	8.E+02	8.E+02	1.E+03	8.E+02	8.E+02	8.E+02	1.E+03
Transformation, to shrub land, sclerophyllous	resource	m^2	6.E+02	8.E+02	6.E+02	8.E+02	8.E+02	1.E+03	8.E+02	8.E+02	8.E+02	1.E+03
Uranium-234	air	kBq	6.E+02	8.E+02	6.E+02	8.E+02	8.E+02	1.E+03	6.E+02	8.E+02	6.E+02	1.E+03
Cobalt	water	kg	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02	1.E+03
Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude	resource	kg	1.E+03	8.E+02	1.E+03	9.E+02	9.E+02	-6.E+02	8.E+02	9.E+02	8.E+02	2.E+03

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
ore, in ground												
Butane	air	kg	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	-8.E+02	2.E+03	1.E+03	1.E+03	-3.E+03
Benzene	air	kg	1.E+03	1.E+03	9.E+02	9.E+02	9.E+02	5.E+02	8.E+02	9.E+02	8.E+02	1.E+03
Fatty Acid (unspecified)	water	kg	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02	9.E+02
Chlorate	water	kg	3.E+02	6.E+02	3.E+02	6.E+02	6.E+02	1.E+03	6.E+02	6.E+02	6.E+02	4.E+03
Methane, dichlorodifluoro-, CFC-12	air	kg	2.E+03	1.E+03	1.E+03	1.E+03	1.E+03	6.E+02	1.E+03	1.E+03	1.E+03	3.E+02
Hydrocarbons, aliphatic, alkanes, unspecified	air	kg	2.E+03	1.E+03	2.E+03	1.E+03	1.E+03	3.E+02	1.E+03	1.E+03	1.E+03	-2.E+03
Nitrogen, organic bound	water	kg	9.E+02	1.E+03	9.E+02	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03
Uranium-234	water	kBq	9.E+02	9.E+02	9.E+02	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	2.E+03
Sodium	soil	kg	5.E+02	5.E+02	6.E+02	6.E+02	6.E+02	5.E+02	3.E+03	6.E+02	3.E+03	3.E+02
Transformation, to	resource	m^2	2.E+03	1.E+03	2.E+03	1.E+03	1.E+03	1.E+01	1.E+03	1.E+03	1.E+03	-1.E+03

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
industrial area												
Open Loop Output: Hazardous Waste	-	kg	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03
Phosphorus, 18% in apatite, 4% in crude ore, in ground	resource	kg	9.E+02	1.E+03	9.E+02	1.E+03	1.E+03	2.E+03	1.E+03	1.E+03	1.E+03	1.E+03
Cobalt-58	water	kBq	9.E+02	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	2.E+03
Transformation, from shrub land, sclerophyllous	resource	m^2	9.E+02	1.E+03	9.E+02	1.E+03	1.E+03	2.E+03	1.E+03	1.E+03	1.E+03	2.E+03
Uranium-238	air	kBq	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	2.E+03	1.E+03	1.E+03	1.E+03	2.E+03
Uranium-235	water	kBq	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	1.E+03	2.E+03
Titanium, ion	water	kg	2.E+03	1.E+03	2.E+03	1.E+03	1.E+03	5.E+02	2.E+03	1.E+03	2.E+03	1.E+03
Copper, ion	water	kg	9.E+02	1.E+03	9.E+02	1.E+03	1.E+03	3.E+03	2.E+03	2.E+03	2.E+03	3.E+03
Chromium VI	water	kg	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03
Halogenated organic	water	kg	8.E+02	2.E+03	8.E+02	2.E+03	2.E+03	3.E+03	2.E+03	2.E+03	2.E+03	3.E+03

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
compounds - as AOX												
Cerium-144	water	kBq	8.E+02	2.E+03	8.E+02	2.E+03	2.E+03	3.E+03	2.E+03	2.E+03	2.E+03	4.E+03
Fluorides - as total F	water	kg	1.E+04	7.E+03	1.E+02	2.E+02	2.E+02	3.E+02	2.E+02	2.E+02	2.E+02	3.E+02
Vinyl chloride	air	kg	4.E+03	3.E+03	2.E+03	2.E+03	2.E+03	1.E+03	2.E+03	2.E+03	2.E+03	7.E+02
Silicon	air	kg	1.E+03	2.E+03	1.E+03	2.E+03	2.E+03	3.E+03	2.E+03	2.E+03	2.E+03	3.E+03
Hydrocarbons (unspecified)	air	kg	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	3.E+03
Sulphur, in ground	resource	kg	3.E+03	2.E+03	3.E+03	2.E+03	2.E+03	7.E+02	2.E+03	2.E+03	2.E+03	6.E+02
Carboxylic acids, unspecified	water	kg	2.E+03	2.E+03	3.E+03	3.E+03	3.E+03	2.E+03	3.E+03	2.E+03	2.E+03	4.E+02
sodium sulphate, various forms, in ground	resource	kg	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	3.E+03	2.E+03	2.E+03	2.E+03	3.E+03
Transformation, from pasture and meadow	resource	m^2	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	3.E+03	2.E+03	2.E+03	2.E+03	3.E+03
Methyl chloroform	air	kg	4.E+03	3.E+03	2.E+03	2.E+03	2.E+03	1.E+03	2.E+03	2.E+03	2.E+03	7.E+02

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
[1,1,1-Trichloroethane]												
Technetium-99	water	kBq	1.E+03	2.E+03	1.E+03	2.E+03	2.E+03	4.E+03	2.E+03	2.E+03	2.E+03	4.E+03
Technetium-99	air	kBq	1.E+03	2.E+03	1.E+03	2.E+03	2.E+03	4.E+03	2.E+03	2.E+03	2.E+03	4.E+03
Manganese	water	kg	1.E+03	2.E+03	1.E+03	2.E+03	2.E+03	4.E+03	2.E+03	2.E+03	2.E+03	4.E+03
Methane, chlorodifluoro-, HCFC-22	air	kg	4.E+03	3.E+03	2.E+03	2.E+03	2.E+03	1.E+03	2.E+03	2.E+03	2.E+03	7.E+02
Nitrogen	water	kg	-1.E+03	-3.E+03	-1.E+03	-3.E+03	-3.E+03	-5.E+03	2.E+04	-3.E+03	2.E+04	-5.E+03
Occupation, traffic area, rail network	resource	m2a	9.E+03	5.E+03	9.E+03	5.E+03	5.E+03	-4.E+03	5.E+03	5.E+03	5.E+03	-2.E+04
Hydrocarbons, unspecified	water	kg	3.E+03	3.E+03	3.E+03	3.E+03	3.E+03	2.E+03	3.E+03	3.E+03	3.E+03	2.E+03
Hydrochlorofluorocarbons (HCFCs)	air	kg	5.E+03	4.E+03	3.E+03	3.E+03	3.E+03	2.E+03	3.E+03	3.E+03	3.E+03	9.E+02
Manganese-54	air	kBq	1.E+03	3.E+03	1.E+03	3.E+03	3.E+03	5.E+03	3.E+03	3.E+03	3.E+03	6.E+03
Manganese-54	water	kBq	1.E+03	3.E+03	1.E+03	3.E+03	3.E+03	5.E+03	3.E+03	3.E+03	3.E+03	6.E+03

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Open Loop Output: Slags and Ash (unspecified)	-	kg	3.E+03	3.E+03	3.E+03	3.E+03	3.E+03	3.E+03	3.E+03	3.E+03	3.E+03	2.E+03
Basalt (in ground)	resource	kg	3.E+03	3.E+03	4.E+03	4.E+03	4.E+03	2.E+03	4.E+03	4.E+03	3.E+03	2.E+03
Hydrogen sulfide	air	kg	6.E+03	5.E+03	4.E+03	4.E+03	4.E+03	2.E+03	3.E+03	3.E+03	3.E+03	1.E+03
Zinc	water	kg	8.E+03	6.E+03	3.E+03	3.E+03	3.E+03	2.E+03	3.E+03	3.E+03	3.E+03	-8.E+02
Chlorofluorocarbons (CFCs)	air	kg	7.E+03	5.E+03	4.E+03	3.E+03	3.E+03	2.E+03	3.E+03	3.E+03	3.E+03	1.E+03
Hydrogen fluoride	air	kg	9.E+03	5.E+03	3.E+03	3.E+03	3.E+03	4.E+03	3.E+03	3.E+03	3.E+03	8.E+02
Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore, in ground	resource	kg	2.E+03	2.E+03	2.E+03	2.E+03	2.E+03	-2.E+02	2.E+03	3.E+03	3.E+03	2.E+04
Occupation, shrub land, sclerophyllous	resource	m2a	3.E+03	4.E+03	3.E+03	4.E+03	4.E+03	5.E+03	4.E+03	4.E+03	4.E+03	5.E+03

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Nickel, ion	water	kg	4.E+03	4.E+03	4.E+03	4.E+03	4.E+03	4.E+03	4.E+03	4.E+03	4.E+03	4.E+03
Hydrogen chloride	air	kg	8.E+03	4.E+03	5.E+03	3.E+03	3.E+03	8.E+02	2.E+03	4.E+03	4.E+03	8.E+03
Xylene - all isomers	air	kg	8.E+03	6.E+03	4.E+03	4.E+03	4.E+03	2.E+03	4.E+03	4.E+03	4.E+03	2.E+03
Strontium-90	air	kBq	2.E+03	4.E+03	2.E+03	4.E+03	4.E+03	8.E+03	4.E+03	4.E+03	4.E+03	9.E+03
Carbon disulphide	air	kg	6.E+03	5.E+03	5.E+03	5.E+03	5.E+03	4.E+03	4.E+03	4.E+03	4.E+03	4.E+03
Carbon-14	water	kBq	2.E+03	4.E+03	2.E+03	4.E+03	4.E+03	8.E+03	4.E+03	4.E+03	4.E+03	9.E+03
Lead-210	water	kBq	4.E+03	4.E+03	4.E+03	5.E+03	5.E+03	6.E+03	5.E+03	5.E+03	4.E+03	6.E+03
Uranium-238	water	kBq	4.E+03	4.E+03	4.E+03	5.E+03	5.E+03	5.E+03	5.E+03	5.E+03	5.E+03	6.E+03
Cesium-134	water	kBq	2.E+03	4.E+03	2.E+03	4.E+03	4.E+03	8.E+03	4.E+03	4.E+03	4.E+03	9.E+03
Aluminum	air	kg	6.E+03	5.E+03	6.E+03	5.E+03	5.E+03	3.E+03	5.E+03	5.E+03	5.E+03	7.E+02
Ammonia	air	kg	3.E+03	3.E+03	3.E+03	3.E+03	3.E+03	2.E+03	1.E+04	3.E+03	1.E+04	8.E+03
Occupation, construction site	resource	m2a	5.E+03	7.E+03	6.E+03	7.E+03	7.E+03	5.E+03	7.E+03	6.E+03	6.E+03	1.E+03
Nitrous oxide	air	kg	4.E+02	-2.E+02	4.E+02	-1.E+02	-3.E+02	-3.E+03	3.E+03	5.E+02	4.E+03	6.E+04
Radium-228	air	kBq	3.E+03	6.E+03	3.E+03	6.E+03	6.E+03	1.E+04	6.E+03	6.E+03	6.E+03	1.E+04

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Hydrogen	air	kg	1.E+04	8.E+03	8.E+03	7.E+03	7.E+03	4.E+03	6.E+03	6.E+03	6.E+03	2.E+03
Magnesium	water	kg	9.E+03	6.E+03	9.E+03	7.E+03	7.E+03	1.E+03	4.E+03	7.E+03	5.E+03	9.E+03
Particulates, > 2.5 um, and < 10um	air	kg	3.E+04	1.E+04	3.E+04	2.E+04	2.E+04	-2.E+04	2.E+04	2.E+04	2.E+04	-7.E+04
Water, salt, sole	resource	m3	6.E+03	6.E+03	8.E+03	7.E+03	7.E+03	6.E+03	7.E+03	7.E+03	7.E+03	3.E+03
Chlorobenzene (C6H5Cl)	soil	kg	1.E+04	9.E+03	7.E+03	7.E+03	7.E+03	4.E+03	7.E+03	7.E+03	6.E+03	2.E+03
Chloride	soil	kg	4.E+03	4.E+03	4.E+03	4.E+03	4.E+03	5.E+03	2.E+04	4.E+03	2.E+04	5.E+03
Transformation, to unknown	resource	m^2	9.E+03	9.E+03	8.E+03	8.E+03	8.E+03	8.E+03	8.E+03	8.E+03	7.E+03	4.E+03
Fluorspar, 92%, in ground	resource	kg	6.E+03	8.E+03	6.E+03	8.E+03	8.E+03	1.E+04	8.E+03	8.E+03	8.E+03	1.E+04
Polonium-210	water	kBq	6.E+03	8.E+03	6.E+03	8.E+03	8.E+03	1.E+04	8.E+03	8.E+03	8.E+03	1.E+04
Phosphate	water	kg	1.E+04	1.E+04	8.E+03	7.E+03	7.E+03	6.E+03	7.E+03	7.E+03	7.E+03	7.E+03
Transformation, to permanent crop	resource	m^2	4.E+03	8.E+03	4.E+03	8.E+03	8.E+03	2.E+04	8.E+03	8.E+03	8.E+03	2.E+04
Plutonium-241	water	kBq	4.E+03	8.E+03	4.E+03	8.E+03	8.E+03	2.E+04	8.E+03	8.E+03	8.E+03	2.E+04

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Plutonium-241	air	kBq	4.E+03	8.E+03	4.E+03	8.E+03	8.E+03	2.E+04	8.E+03	8.E+03	8.E+03	2.E+04
Gypsum, in ground	resource	kg	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	4.E+03
Carbon Monoxide (CO)	air	kg	5.E+03	9.E+03	5.E+03	9.E+03	9.E+03	2.E+04	1.E+04	9.E+03	1.E+04	2.E+04
Particulates - PM10 and smaller only	air	kg	2.E+03	6.E+03	9.E+03	9.E+03	9.E+03	9.E+03	2.E+04	9.E+03	2.E+04	2.E+04
Aluminum, 24% in bauxite, 11% in crude ore, in ground	resource	kg	4.E+04	1.E+04	4.E+04	1.E+04	1.E+04	-4.E+04	2.E+04	1.E+04	2.E+04	-1.E+04
Carbonate	water	kg	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04
Transformation, to water bodies, artificial	resource	m^2	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	4.E+03
Particulates, < 2.5 um	air	kg	2.E+04	1.E+04	2.E+04	1.E+04	1.E+04	-3.E+03	1.E+04	1.E+04	1.E+04	-1.E+04
Iron, ion	water	kg	2.E+04	1.E+04	2.E+04	1.E+04	1.E+04	7.E+03	1.E+04	1.E+04	1.E+04	1.E+04
Iodine-129	water	kBq	6.E+03	1.E+04	6.E+03	1.E+04	1.E+04	2.E+04	1.E+04	1.E+04	1.E+04	3.E+04
Thorium-228	air	kBq	6.E+03	1.E+04	6.E+03	1.E+04	1.E+04	2.E+04	1.E+04	1.E+04	1.E+04	3.E+04

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Iodine-129	air	kBq	6.E+03	1.E+04	6.E+03	1.E+04	1.E+04	2.E+04	1.E+04	1.E+04	1.E+04	3.E+04
Lignite (in ground)	resource	kg	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	1.E+04	2.E+04	2.E+04	2.E+04	-2.E+04
Carbon (C)	resource	kg	7.E+03	1.E+04	7.E+03	1.E+04	1.E+04	3.E+04	1.E+04	1.E+04	1.E+04	3.E+04
Nitrate	water	kg	1.E+04	2.E+04	1.E+04	2.E+04	2.E+04	2.E+04	1.E+04	2.E+04	1.E+04	3.E+04
Salts (unspecified)	water	kg	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04
Sand, unspecified, in ground	resource	kg	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	1.E+04	2.E+04	2.E+04	2.E+04	-1.E+03
Cobalt-60	water	kBq	9.E+03	2.E+04	9.E+03	2.E+04	2.E+04	4.E+04	2.E+04	2.E+04	2.E+04	4.E+04
Transformation, from mineral extraction site	resource	m^2	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	2.E+04	1.E+04
Ruthenium-106	water	kBq	9.E+03	2.E+04	9.E+03	2.E+04	2.E+04	4.E+04	2.E+04	2.E+04	2.E+04	4.E+04
Ruthenium-106	air	kBq	9.E+03	2.E+04	9.E+03	2.E+04	2.E+04	4.E+04	2.E+04	2.E+04	2.E+04	4.E+04
Barite, 15% in crude ore, in ground	resource	kg	4.E+04	4.E+04	6.E+04	5.E+04	5.E+04	-2.E+04	5.E+04	4.E+04	4.E+04	-1.E+05
Oils, unspecified	water	kg	3.E+04	3.E+04	4.E+04	4.E+04	4.E+04	4.E+03	4.E+04	3.E+04	3.E+04	-4.E+04

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Uranium alpha	air	kBq	1.E+04	2.E+04	1.E+04	2.E+04	2.E+04	5.E+04	3.E+04	2.E+04	3.E+04	5.E+04
Zinc (Zn, ore)	resource	kg	1.E+04	2.E+04	1.E+04	3.E+04	3.E+04	5.E+04	2.E+04	3.E+04	2.E+04	5.E+04
Radium-224	water	kBq	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04	2.E+04
Dolomite, in ground	resource	kg	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04	3.E+04
Water, salt, ocean	resource	m3	2.E+04	3.E+04	2.E+04	3.E+04	3.E+04	4.E+04	3.E+04	3.E+04	3.E+04	5.E+04
Oils, unspecified	soil	kg	4.E+04	3.E+04	5.E+04	4.E+04	4.E+04	3.E+04	4.E+04	4.E+04	4.E+04	1.E+04
Water, well, in ground	resource	m3	3.E+04	4.E+04	3.E+04	4.E+04	4.E+04	5.E+04	3.E+04	4.E+04	4.E+04	5.E+04
Total organic carbon (TOC or COD/3)	water	kg	6.E+04	5.E+04	7.E+04	6.E+04	6.E+04	2.E+04	6.E+04	6.E+04	6.E+04	-3.E+04
Uranium alpha	water	kBq	4.E+04	4.E+04	4.E+04	4.E+04	4.E+04	5.E+04	5.E+04	4.E+04	5.E+04	7.E+04
Solved solids	water	kg	5.E+04	5.E+04	5.E+04	5.E+04	5.E+04	5.E+04	5.E+04	5.E+04	5.E+04	5.E+04
DOC, Dissolved Organic Carbon	water	kg	6.E+04	6.E+04	7.E+04	7.E+04	6.E+04	3.E+04	7.E+04	6.E+04	6.E+04	-2.E+04
Radium-228	water	kBq	6.E+04	6.E+04	7.E+04	7.E+04	7.E+04	6.E+04	7.E+04	6.E+04	6.E+04	4.E+04

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Open Loop Output: Mining Waste	-	kg	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04
Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore, in ground	resource	kg	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04	6.E+04	7.E+04
Occupation, water courses, artificial	resource	m2a	4.E+04	6.E+04	4.E+04	6.E+04	6.E+04	9.E+04	6.E+04	6.E+04	6.E+04	9.E+04
Thorium-230	air	kBq	3.E+04	6.E+04	3.E+04	6.E+04	6.E+04	1.E+05	6.E+04	6.E+04	6.E+04	1.E+05
Cesium-137	water	kBq	5.E+04	6.E+04	5.E+04	6.E+04	6.E+04	7.E+04	6.E+04	6.E+04	7.E+04	9.E+04
Clay, bentonite, in ground	resource	kg	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	4.E+04	1.E+05	1.E+05	1.E+05	-2.E+05
Transformation, to mineral extraction site	resource	m^2	7.E+04	7.E+04	9.E+04	8.E+04	8.E+04	7.E+04	8.E+04	8.E+04	8.E+04	3.E+04

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Transformation, from unknown	resource	m^2	7.E+04	7.E+04	9.E+04	9.E+04	9.E+04	7.E+04	8.E+04	8.E+04	8.E+04	3.E+04
TiO2, 45-60% in Ilmenite, in ground	resource	kg	8.E+04	8.E+04	8.E+04	8.E+04	8.E+04	8.E+04	8.E+04	8.E+04	8.E+04	9.E+04
Occupation, industrial area	resource	m2a	1.E+05	9.E+04	1.E+05	1.E+05	1.E+05	4.E+04	1.E+05	1.E+05	1.E+05	-2.E+04
Thorium-230	water	kBq	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	2.E+05
Carbon-14	air	kBq	2.E+05	1.E+05	2.E+05	1.E+05	1.E+05	-5.E+04	1.E+05	1.E+05	1.E+05	5.E+04
Aluminum	water	kg	6.E+04	1.E+05	6.E+04	1.E+05	1.E+05	2.E+05	1.E+05	1.E+05	1.E+05	2.E+05
Sulphate	water	kg	2.E+05	1.E+05	2.E+05	1.E+05	1.E+05	7.E+04	8.E+04	1.E+05	8.E+04	1.E+05
BOD5, Biological Oxygen Demand	water	kg	1.E+05	1.E+05	2.E+05	2.E+05	2.E+05	4.E+04	2.E+05	1.E+05	1.E+05	-1.E+05
Thorium-228	water	kBq	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	7.E+04
Molybdenum, 0.11% in sulfide, Mo 0.41% and Cu 0.36% in	resource	kg	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
crude ore, in ground												
Chromium, 25.5 in chromite, 11.6% in crude ore, in ground	resource	kg	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05	1.E+05
Carbon dioxide (CO_2)	air	kg	6.E+04	1.E+05	6.E+04	1.E+05	1.E+05	3.E+05	1.E+05	1.E+05	1.E+05	3.E+05
Magnesite, 60% in crude ore, in ground	resource	kg	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	1.E+05	2.E+05	2.E+05	2.E+05	2.E+05
Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground	resource	kg	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05
Coal (in ground)	resource	kg	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05	2.E+05
Nitrogen oxides (NO and NO_2 as NO_2)	air	kg	1.E+05	9.E+04	2.E+05	1.E+05	2.E+05	6.E+05	1.E+05	2.E+05	2.E+05	6.E+05
Open Loop Output:	-	kg	3.E+05	3.E+05	3.E+05	3.E+05	3.E+05	3.E+05	3.E+05	3.E+05	3.E+05	3.E+05

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Waste Unspecified												
Methane, (unspecified)	air	kg	1.E+05	2.E+05	1.E+05	2.E+05	2.E+05	5.E+05	3.E+05	2.E+05	3.E+05	5.E+05
Ammonia (NH4+, NH_3, as N)	water	kg	2.E+06	1.E+06	2.E+04	3.E+04	3.E+04	5.E+04	3.E+04	3.E+04	3.E+04	4.E+04
Sulphur oxides (SO2 and SO3 as SO2)	air	kg	8.E+03	2.E+05	4.E+05	4.E+05	4.E+05	2.E+05	4.E+05	4.E+05	4.E+05	2.E+05
Carbon monoxide, biogenic	air	kg	-4.E+03	2.E+05	3.E+05	3.E+05	3.E+05	1.E+06	3.E+05	3.E+05	2.E+05	1.E+05
Occupation, arable	resource	m2a	3.E+05	3.E+05	3.E+05	3.E+05	3.E+05	5.E+05	3.E+05	3.E+05	3.E+05	5.E+05
Occupation, mineral extraction site	resource	m2a	5.E+05	5.E+05	6.E+05	6.E+05	6.E+05	5.E+05	6.E+05	5.E+05	5.E+05	2.E+05
Occupation, dump site	resource	m2a	6.E+05	6.E+05	6.E+05	6.E+05	6.E+05	5.E+05	6.E+05	6.E+05	6.E+05	4.E+05
Occupation, permanent crop	resource	m2a	3.E+05	6.E+05	3.E+05	6.E+05	6.E+05	1.E+06	6.E+05	6.E+05	6.E+05	1.E+06
Nickel, 1.98% in silicates, 1.04% in	resource	kg	6.E+05	6.E+05	6.E+05	6.E+05	6.E+05	6.E+05	6.E+05	6.E+05	6.E+05	7.E+05

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
crude ore, in ground												
Transformation, from arable	resource	m^2	5.E+05	6.E+05	5.E+05	6.E+05	6.E+05	1.E+06	6.E+05	6.E+05	6.E+05	1.E+06
Transformation, to arable	resource	m^2	5.E+05	6.E+05	5.E+05	6.E+05	6.E+05	1.E+06	6.E+05	6.E+05	6.E+05	1.E+06
Energy, kinetic, flow, in wind	resource	MJ	1.E+06	8.E+05	1.E+06	8.E+05	8.E+05	3.E+04	8.E+05	8.E+05	9.E+05	7.E+05
Calcium, ion	water	kg	1.E+05	2.E+05	1.E+05	2.E+05	2.E+05	2.E+05	2.E+05	6.E+05	7.E+05	6.E+06
Iron, 46% in ore, 25% in crude ore, in ground	resource	kg	7.E+06	4.E+06	7.E+06	4.E+06	4.E+06	-4.E+06	4.E+06	4.E+06	4.E+06	-2.E+07
COD, Chemical Oxygen Demand	water	kg	6.E+05	9.E+05	6.E+05	9.E+05	9.E+05	1.E+06	9.E+05	9.E+05	9.E+05	1.E+06
Water, unspecified natural origin	resource	m3	8.E+05	9.E+05	9.E+05	1.E+06	1.E+06	1.E+06	1.E+06	1.E+06	1.E+06	1.E+06
Sodium chloride, in ground	resource	kg	5.E+05	7.E+05	5.E+05	7.E+05	7.E+05	1.E+06	7.E+05	7.E+05	7.E+05	4.E+06

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Silicon	water	kg	1.E+06	1.E+06	1.E+06	1.E+06	1.E+06	2.E+06	1.E+06	1.E+06	1.E+06	2.E+06
Energy, solar	resource	MJ	8.E+05	1.E+06	8.E+05	1.E+06	1.E+06	3.E+06	1.E+06	1.E+06	1.E+06	3.E+06
Radium-226	air	kBq	7.E+05	1.E+06	7.E+05	1.E+06	1.E+06	3.E+06	2.E+06	1.E+06	2.E+06	3.E+06
Potassium, ion	water	kg	2.E+06	2.E+06	2.E+06	2.E+06	2.E+06	1.E+06	1.E+06	2.E+06	2.E+06	3.E+06
Radium-226	water	kBq	1.E+06	2.E+06	1.E+06	2.E+06	2.E+06	3.E+06	2.E+06	2.E+06	2.E+06	3.E+06
Sodium, ion	water	kg	3.E+06	3.E+06	2.E+06	2.E+06	2.E+06	2.E+06	2.E+06	2.E+06	2.E+06	3.E+06
Calcite, in ground	resource	kg	6.E+06	6.E+06	8.E+06	8.E+06	8.E+06	7.E+06	8.E+06	9.E+06	9.E+06	6.E+06
Chlorides - as total Cl	water	kg	9.E+06	8.E+06	7.E+06	6.E+06	6.E+06	5.E+06	6.E+06	7.E+06	7.E+06	2.E+07
Methane, biogenic	air	kg	8.E+07	6.E+07	4.E+07	4.E+07	4.E+07	2.E+07	4.E+07	4.E+07	4.E+07	2.E+07
water	air	kg	9.E+03	7.E+03	9.E+03	7.E+03	7.E+03	4.E+03	2.E+07	7.E+03	2.E+07	8.E+08
Radioactive species, other beta emitters	air	kBq	1.E+08	1.E+08	1.E+08	1.E+08	1.E+08	1.E+08	1.E+08	1.E+08	2.E+08	4.E+07
Hydrogen-3, Tritium	air	kBq	6.E+07	1.E+08	6.E+07	1.E+08	1.E+08	2.E+08	1.E+08	1.E+08	1.E+08	3.E+08
Hydrogen-3, Tritium	water	kBq	1.E+08	2.E+08	1.E+08	2.E+08	2.E+08	2.E+08	2.E+08	2.E+08	2.E+08	3.E+08

Pollutant	EC	Unit	S0	S1	S2-A	S2-B	S2-C	S2-D	S3-A	S3-B	S3-C	S4
Gravel, in ground	resource	kg	2.E+08	2.E+08	2.E+08	2.E+08	2.E+08	2.E+08	2.E+08	2.E+08	2.E+08	1.E+08
Radioactive species, Nuclides, unspecified	water	kBq	1.E+08	2.E+08	1.E+08	2.E+08	2.E+08	5.E+08	3.E+08	2.E+08	3.E+08	5.E+08
Water	water	kg	3.E+08	3.E+08	3.E+08	3.E+08	3.E+08	4.E+08	3.E+08	4.E+08	4.E+08	7.E+08
Carbon dioxide, biogenic	air	kg	3.E+08	3.E+08	4.E+08	3.E+08	3.E+08	4.E+08	4.E+08	4.E+08	4.E+08	7.E+08
Clay, unspecified, in ground	resource	kg	6.E+08	5.E+08	5.E+08	5.E+08	5.E+08	5.E+08	5.E+08	5.E+08	4.E+08	2.E+08
Water, turbine use, unspecified natural origin	resource	m3	4.E+08	5.E+08	4.E+08	5.E+08	5.E+08	9.E+08	6.E+08	5.E+08	6.E+08	9.E+08
Noble gases, radioactive, unspecified	air	kBq	2.E+09	1.E+09	2.E+09	1.E+09	1.E+09	-4.E+08	1.E+09	1.E+09	1.E+09	6.E+08
Radon-222	air	kBq	4.E+09	2.E+09	4.E+09	3.E+09	3.E+09	-7.E+07	3.E+09	3.E+09	3.E+09	2.E+09

Appendix M: Life Cycle Inventory (LCI) for e-waste scenarios

(For Chapter 5)

Functional unit: 23,111 ton. Unit: kg.

Emission category (EC)
1: Deposited goods
2: Emissions to agricultural soil
3: Emissions to air
4: Emissions to fresh water
5: Emissions to industrial soil
6: Resources

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
1	Overburden (deposited)	0.0.E+00	-9.0.E+06	6.0.E+05	-9.0.E+06	-1.0.E+07	-4.0.E+07	-4.0.E+07
1	Tailings (deposited)	0.0.E+00	-3.0.E+06	6.0.E+03	-3.0.E+06	-1.0.E+07	-2.0.E+07	-2.0.E+07
1	Radioactive tailings	0.0.E+00	1.0.E+02	1.0.E+02	2.0.E+01	-8.0.E+01	-1.0.E+04	-1.0.E+04
1	Low radioactive wastes	0.0.E+00	2.0.E+00	2.0.E+00	8.0.E-01	-7.0.E-01	-2.0.E+02	-2.0.E+02
1	Medium radioactive wastes	0.0.E+00	1.0.E+00	1.0.E+00	6.0.E-01	2.0.E-01	-1.0.E+02	-1.0.E+02
1	High radioactive waste	0.0.E+00	2.0.E-01	1.0.E-01	-5.0.E-02	-2.0.E-01	-2.0.E+01	-2.0.E+01
1	Spoil (deposited)	0.0.E+00	3.0.E+04	2.0.E+05	2.0.E+05	2.0.E+05	1.0.E+05	1.0.E+05

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
1	Waste (deposited)	0.0.E+00	-5.0.E+04	2.0.E+07	2.0.E+07	2.0.E+07	2.0.E+07	2.0.E+07
2	Selenium	1.0.E+00	2.0.E-01	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
2	Antimony	9.0.E-01	4.0.E-01	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
2	Barium	1.0.E+00	2.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
2	Zinc (+II)	2.0.E+01	2.0.E+01	8.0.E-02	-5.0.E-03	-5.0.E-02	3.0.E-01	3.0.E-01
2	Lead (+II)	4.0.E+01	3.0.E+01	3.0.E-02	4.0.E-03	-8.0.E-03	4.0.E-02	4.0.E-02
2	Tin (+IV)	8.0.E+01	9.0.E+01	5.0.E-08	2.0.E-09	-6.0.E-08	-6.0.E-06	-6.0.E-06
2	Iron	2.0.E+02	3.0.E+02	4.0.E-08	2.0.E-09	-4.0.E-08	-4.0.E-06	-4.0.E-06
2	Aluminum	6.0.E+02	3.0.E+02	2.0.E-07	1.0.E-08	-2.0.E-07	-2.0.E-05	-2.0.E-05
2	Copper (+II)	4.0.E+03	5.0.E+03	2.0.E-02	-1.0.E-02	-3.0.E-02	2.0.E-01	2.0.E-01
2	Pesticides to agricultural soil	2.0.E+04	3.0.E+03	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
2	Bromine	2.0.E+04	3.0.E+03	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
3	Inorganic 3	6.0.E+04	-3.0.E+06	4.0.E+06	-1.0.E+06	-7.0.E+06	-5.0.E+07	-5.0.E+07
3	Water vapour	0.0.E+00	-1.0.E+06	1.0.E+06	-2.0.E+06	-7.0.E+06	-3.0.E+07	-3.0.E+07

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
3	Water (evapotranspiration)	0.0.E+00	-8.0.E+05	2.0.E+06	1.0.E+06	1.0.E+06	-3.0.E+07	-3.0.E+07
3	Carbon dioxide (biotic)	0.0.E+00	1.0.E+04	3.0.E+04	4.0.E+04	7.0.E+04	-5.0.E+05	-5.0.E+05
3	Oxygen	0.0.E+00	2.0.E+02	1.0.E+04	1.0.E+04	1.0.E+04	-7.0.E+04	-7.0.E+04
3	Sulphur dioxide	1.0.E+00	-3.0.E+03	1.0.E+03	-2.0.E+03	-1.0.E+04	-2.0.E+04	-2.0.E+04
3	Carbon monoxide	8.0.E+01	-9.0.E+03	1.0.E+03	-8.0.E+03	-4.0.E+03	-2.0.E+04	-2.0.E+04
3	Nitrogen oxides	5.0.E+00	-2.0.E+03	2.0.E+03	-4.0.E+02	-7.0.E+03	-2.0.E+04	-2.0.E+04
3	Methane	2.0.E+04	2.0.E+03	2.0.E+03	1.0.E+03	-2.0.E+03	-2.0.E+04	-2.0.E+04
3	Carbon dioxide (land use change)	0.0.E+00	-1.0.E+02	7.0.E+02	5.0.E+02	4.0.E+02	-3.0.E+03	-3.0.E+03
3	Ethane	0.0.E+00	6.0.E+00	3.0.E+01	3.0.E+01	5.0.E+01	-8.0.E+02	-8.0.E+02
3	Propane	0.0.E+00	-2.0.E+00	4.0.E+01	3.0.E+01	5.0.E+01	-6.0.E+02	-6.0.E+02
3	Nitrogen (atmospheric nitrogen)	0.0.E+00	-2.0.E+02	2.0.E+02	-1.0.E+01	2.0.E+03	-2.0.E+03	-2.0.E+03
3	NMVOC (unspecified)	0.0.E+00	-3.0.E+01	2.0.E+02	1.0.E+02	8.0.E+01	-6.0.E+02	-6.0.E+02
3	Hydrogen sulfide	0.0.E+00	1.0.E-01	1.0.E+01	1.0.E+01	2.0.E+01	-4.0.E+02	-4.0.E+02

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
3	Methane (biotic)	2.0.E+01	3.0.E+01	1.0.E+01	3.0.E+01	4.0.E+01	-4.0.E+02	-4.0.E+02
3	Nitrous oxide (laughing gas)	6.0.E-01	-1.0.E+01	1.0.E+01	-6.0.E+00	-6.0.E+01	-2.0.E+02	-2.0.E+02
3	Butane (n-butane)	0.0.E+00	2.0.E+00	1.0.E+01	1.0.E+01	2.0.E+01	-2.0.E+02	-2.0.E+02
3	Pentane (n-pentane)	0.0.E+00	1.0.E+00	6.0.E+00	5.0.E+00	6.0.E+00	-2.0.E+02	-2.0.E+02
3	Manganese (+II)	1.0.E+00	-4.0.E+01	3.0.E-01	-4.0.E+01	-3.0.E+01	-8.0.E+01	-8.0.E+01
3	Hydrocarbons (unspecified)	0.0.E+00	-2.0.E+01	4.0.E-01	-2.0.E+01	-1.0.E+01	-4.0.E+01	-4.0.E+01
3	Xylene (dimethyl benzene)	0.0.E+00	-3.0.E+00	1.0.E+01	1.0.E+01	-6.0.E+00	-7.0.E+01	-7.0.E+01
3	Formaldehyde (methanal)	2.0.E+00	2.0.E+00	1.0.E+00	-2.0.E-03	-1.0.E+00	-5.0.E+01	-5.0.E+01
3	Hydrogen fluoride	2.0.E+00	-2.0.E+00	4.0.E-01	-1.0.E+01	-1.0.E+01	-3.0.E+01	-3.0.E+01
3	Carbon dioxide (aviation)	0.0.E+00	2.0.E+00	1.0.E+00	3.0.E+00	4.0.E+00	-4.0.E+01	-4.0.E+01
3	Dust (PM10)	0.0.E+00	-9.0.E+00	1.0.E-01	-9.0.E+00	-5.0.E+00	-2.0.E+01	-2.0.E+01
3	Alkane (unspecified)	0.0.E+00	-1.0.E+00	2.0.E-01	-2.0.E+00	-6.0.E+00	-2.0.E+01	-2.0.E+01
3	Alkene (unspecified)	0.0.E+00	-7.0.E-01	2.0.E-01	-7.0.E-01	-5.0.E+00	-2.0.E+01	-2.0.E+01
3	Ethyl benzene	2.0.E+00	1.0.E+00	2.0.E-01	-6.0.E-01	-5.0.E+00	-2.0.E+01	-2.0.E+01

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
3	Fluoride	0.0.E+00	7.0.E-03	3.0.E-02	-5.0.E+00	-5.0.E+00	-9.0.E+00	-9.0.E+00
3	Boron compounds (unspecified)	0.0.E+00	4.0.E-02	1.0.E-01	-2.0.E-02	-3.0.E+00	-1.0.E+01	-1.0.E+01
3	Lead (+II)	9.0.E+01	1.0.E+01	1.0.E-01	-2.0.E+01	-2.0.E+01	-4.0.E+01	-4.0.E+01
3	Acetic acid	0.0.E+00	-8.0.E-01	2.0.E-01	-8.0.E-01	-1.0.E+00	-8.0.E+00	-8.0.E+00
3	Benzene	5.0.E+00	5.0.E+00	6.0.E-01	4.0.E-01	1.0.E+00	-2.0.E+01	-2.0.E+01
3	Chromium	4.0.E-01	-1.0.E+00	1.0.E-02	-1.0.E+00	-1.0.E+00	-2.0.E+00	-2.0.E+00
3	Argon	0.0.E+00	2.0.E-01	1.0.E-01	3.0.E-01	5.0.E-01	-5.0.E+00	-5.0.E+00
3	Vanadium (+III)	3.0.E-02	-6.0.E-01	3.0.E-02	-6.0.E-01	-8.0.E-01	-2.0.E+00	-2.0.E+00
3	Group PAH to air	0.0.E+00	-1.0.E-03	4.0.E-03	-1.0.E+00	-1.0.E+00	-2.0.E+00	-2.0.E+00
3	Polycyclic aromatic hydrocarbons (PAH, carcinogenic)	0.0.E+00	2.0.E-03	3.0.E-03	-1.0.E+00	-1.0.E+00	-2.0.E+00	-2.0.E+00
3	Methanol	0.0.E+00	-5.0.E-01	1.0.E-02	-6.0.E-01	-8.0.E-01	-2.0.E+00	-2.0.E+00
3	Tetrafluoromethane	0.0.E+00	2.0.E-04	1.0.E-04	-8.0.E-01	-8.0.E-01	-1.0.E+00	-1.0.E+00
3	Ethanol	0.0.E+00	-4.0.E-01	1.0.E-02	-5.0.E-01	-6.0.E-01	-1.0.E+00	-1.0.E+00

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
3	Chloride (unspecified)	0.0.E+00	-3.0.E-02	1.0.E-01	4.0.E-02	-1.0.E+00	-2.0.E+00	-2.0.E+00
3	Propene (propylene)	0.0.E+00	-6.0.E-02	3.0.E-02	-5.0.E-02	-4.0.E-01	-2.0.E+00	-2.0.E+00
3	Selenium	1.0.E-01	-3.0.E-02	9.0.E-03	-5.0.E-02	-7.0.E-01	-1.0.E+00	-1.0.E+00
3	Acetone (dimethylcetone)	0.0.E+00	-2.0.E-01	6.0.E-03	-2.0.E-01	-3.0.E-01	-7.0.E-01	-7.0.E-01
3	Arsenic (+V)	3.0.E+00	-9.0.E-02	7.0.E-03	-5.0.E-01	-9.0.E-01	-1.0.E+00	-1.0.E+00
3	Hydrocarbons, aromatic	0.0.E+00	-8.0.E-02	2.0.E-03	-9.0.E-02	-1.0.E-01	-3.0.E-01	-3.0.E-01
3	Sulphur trioxide	0.0.E+00	2.0.E-02	3.0.E-02	4.0.E-02	6.0.E-02	-4.0.E-01	-4.0.E-01
3	R 116 (hexafluoroethane)	0.0.E+00	3.0.E-05	2.0.E-05	-1.0.E-01	-1.0.E-01	-2.0.E-01	-2.0.E-01
3	Fatty methylester	0.0.E+00	6.0.E-01	5.0.E-10	1.0.E-09	2.0.E-09	-2.0.E-08	-2.0.E-08
3	Mercury (+II)	4.0.E-01	6.0.E-02	3.0.E-01	2.0.E-01	2.0.E-01	2.0.E-01	2.0.E-01
3	Acetaldehyde (Ethanal)	2.0.E+00	2.0.E+00	7.0.E-03	-2.0.E-01	-3.0.E-01	-7.0.E-01	-7.0.E-01
3	Chlorine	0.0.E+00	-1.0.E-01	8.0.E-01	6.0.E-01	7.0.E-01	4.0.E-01	4.0.E-01
3	PAH, polycyclic aromatic hydrocarbons	2.0.E+00	2.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
3	Styrene	3.0.E+00	3.0.E+00	1.0.E-04	-3.0.E-02	-5.0.E-02	-7.0.E-02	-7.0.E-02
3	Toluene (methyl benzene)	2.0.E+00	2.0.E+00	7.0.E+00	7.0.E+00	5.0.E+00	-8.0.E+00	-8.0.E+00
3	Nitrogen dioxide	0.0.E+00	2.0.E-01	2.0.E+00	2.0.E+00	2.0.E+00	9.0.E-01	9.0.E-01
3	Vinyl chloride (VCM; chloroethene)	0.0.E+00	8.0.E-06	3.0.E+00	3.0.E+00	3.0.E+00	5.0.E-05	5.0.E-05
3	Phosphorus	1.0.E+01	2.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
3	Cobalt	9.0.E+00	1.0.E+00	1.0.E-03	-2.0.E-02	-1.0.E-01	3.0.E+00	3.0.E+00
3	Strontium	3.0.E+01	4.0.E+00	2.0.E-10	-2.0.E-09	-3.0.E-09	-6.0.E-08	-6.0.E-08
3	Cadmium (+II)	4.0.E+01	5.0.E+00	8.0.E-03	-1.0.E-02	-8.0.E-03	-4.0.E-02	-4.0.E-02
3	Barium	4.0.E+01	8.0.E+00	1.0.E-02	-5.0.E-01	-2.0.E+00	-3.0.E+00	-3.0.E+00
3	Hydrogen fluoride	4.0.E+01	6.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
3	Bromine	6.0.E+01	9.0.E+00	3.0.E-02	-1.0.E-01	-2.0.E-01	-2.0.E+00	-2.0.E+00
3	Nitrogen monoxide	0.0.E+00	7.0.E-01	2.0.E+01	2.0.E+01	2.0.E+01	2.0.E+01	2.0.E+01
3	Mercaptan (unspecified)	0.0.E+00	3.0.E-05	4.0.E+01	4.0.E+01	4.0.E+01	2.0.E-03	2.0.E-03

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
3	Zinc (+II)	1.0.E+02	3.0.E+01	2.0.E-02	-5.0.E+00	-7.0.E+00	-1.0.E+01	-1.0.E+01
3	Hydrogen bromide (hydrobromic acid)	0.0.E+00	1.0.E-06	8.0.E-07	2.0.E-06	3.0.E-06	7.0.E+01	7.0.E+01
3	Antimony	1.0.E+02	2.0.E+01	5.0.E-04	-2.0.E-02	-2.0.E-02	4.0.E+01	4.0.E+01
3	Nickel (+II)	2.0.E+02	3.0.E+01	1.0.E-02	-1.0.E+00	-3.0.E+00	-3.0.E+00	-3.0.E+00
3	Carbon monoxide, non-fossil	1.0.E+02	1.0.E+02	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
3	Tin (+IV)	2.0.E+02	9.0.E+01	5.0.E-03	-2.0.E-01	-8.0.E-01	8.0.E+00	8.0.E+00
3	Sulphate	3.0.E+02	4.0.E+01	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
3	Ammonia	0.0.E+00	-3.0.E+00	9.0.E+00	5.0.E+00	-2.0.E+00	2.0.E+02	2.0.E+02
3	Titanium	1.0.E+03	2.0.E+02	4.0.E-03	-6.0.E-01	-4.0.E-01	-1.0.E+00	-1.0.E+00
3	Aluminum	1.0.E+03	3.0.E+02	8.0.E-04	2.0.E-03	3.0.E-03	-2.0.E-02	-2.0.E-02
3	Hydrogen	0.0.E+00	-1.0.E+00	3.0.E+02	3.0.E+02	3.0.E+02	3.0.E+02	3.0.E+02
3	Hydrogen chloride	2.0.E+03	3.0.E+02	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
3	Bromine	2.0.E+03	3.0.E+02	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
3	Silicon dust	2.0.E+03	4.0.E+02	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
3	ecoinvent long-term to air	4.0.E+03	6.0.E+02	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
3	Hydrogen chloride	1.0.E+02	8.0.E+00	1.0.E+01	-9.0.E+00	-2.0.E+01	3.0.E+03	3.0.E+03
3	Copper (+II)	5.0.E+03	4.0.E+03	1.0.E-02	-6.0.E+00	-8.0.E+00	-1.0.E+01	-1.0.E+01
3	Nitrate	2.0.E+04	3.0.E+03	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
3	Dust (PM2.5)	2.0.E+05	4.0.E+04	7.0.E+01	-4.0.E+02	-7.0.E+02	-2.0.E+03	-2.0.E+03
3	Clean gas	0.0.E+00	-2.0.E+02	6.0.E+04	6.0.E+04	6.0.E+04	5.0.E+04	5.0.E+04
3	Used air	0.0.E+00	-2.0.E+05	8.0.E+04	-2.0.E+05	2.0.E+05	2.0.E+05	2.0.E+05
3	Dust (PM2,5 - PM10)	3.0.E+05	6.0.E+04	4.0.E+03	4.0.E+03	5.0.E+03	4.0.E+03	4.0.E+03
3	Iron	5.0.E+05	1.0.E+05	2.0.E-01	-3.0.E+01	-2.0.E+01	-5.0.E+01	-5.0.E+01
3	Heavy metals to air	5.0.E+05	1.0.E+05	1.0.E+00	-1.0.E+02	-9.0.E+01	-1.0.E+02	-1.0.E+02
3	Dust (> PM10)	6.0.E+05	1.0.E+05	2.0.E+01	-9.0.E+01	-3.0.E+02	-9.0.E+02	-9.0.E+02
3	Carbon dioxide	4.0.E+04	-7.0.E+05	4.0.E+05	-5.0.E+05	-1.0.E+06	5.0.E+06	5.0.E+06
3	3.0.E+00	2.0.E+06	-2.0.E+06	7.0.E+06	1.0.E+06	-9.0.E+06	6.0.E+06	6.0.E+06
3	Exhaust	0.0.E+00	3.0.E+05	3.0.E+06	3.0.E+06	-2.0.E+06	6.0.E+07	6.0.E+07

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
4	Water (river water from technosphere, turbined)	0.0.E+00	1.0.E+08	3.0.E+08	-1.0.E+09	-1.0.E+09	-2.0.E+10	-2.0.E+10
4	Water (river water from technosphere, cooling water)	0.0.E+00	2.0.E+06	6.0.E+06	3.0.E+06	5.0.E+06	-2.0.E+08	-2.0.E+08
4	Water (sea water from technosphere, cooling water)	0.0.E+00	2.0.E+05	4.0.E+05	-2.0.E+06	-2.0.E+06	-7.0.E+07	-7.0.E+07
4	Water (sea water from technosphere, waste water)	0.0.E+00	-1.0.E+03	5.0.E+03	-3.0.E+04	-3.0.E+04	-3.0.E+05	-3.0.E+05
4	Chloride	0.0.E+00	-6.0.E+03	8.0.E+03	1.0.E+02	-7.0.E+03	-5.0.E+04	-5.0.E+04
4	Water (groundwater from technosphere, waste water)	0.0.E+00	1.0.E+03	9.0.E+02	1.0.E+03	-3.0.E+02	-4.0.E+04	-4.0.E+04
4	Sodium (+I)	0.0.E+00	9.0.E+01	2.0.E+02	2.0.E+02	-7.0.E+03	-9.0.E+03	-9.0.E+03
4	Soil loss by erosion into water	0.0.E+00	-9.0.E+01	1.0.E+03	1.0.E+03	1.0.E+03	-1.0.E+04	-1.0.E+04
4	Sulphate	0.0.E+00	-4.0.E+01	3.0.E+02	2.0.E+02	2.0.E+02	-7.0.E+03	-7.0.E+03
4	Solids (suspended)	0.0.E+00	-1.0.E+02	5.0.E+02	2.0.E+02	3.0.E+02	-6.0.E+03	-6.0.E+03
4	Chemical oxygen demand (COD)	0.0.E+00	-1.0.E+02	2.0.E+02	9.0.E+00	-2.0.E+01	-4.0.E+03	-4.0.E+03

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
4	Chloride	0.0.E+00	-1.0.E+03	2.0.E+03	3.0.E+02	1.0.E+03	-4.0.E+03	-4.0.E+03
4	Fluoride	0.0.E+00	9.0.E+01	7.0.E+01	1.0.E+02	2.0.E+02	-3.0.E+03	-3.0.E+03
4	Iron	0.0.E+00	2.0.E+01	6.0.E+01	7.0.E+01	7.0.E+01	-2.0.E+03	-2.0.E+03
4	Calcium (+II)	0.0.E+00	4.0.E+01	1.0.E+02	1.0.E+02	-2.0.E+01	-2.0.E+03	-2.0.E+03
4	Carbon, organically bound	0.0.E+00	-8.0.E+00	1.0.E+02	1.0.E+02	1.0.E+02	-1.0.E+03	-1.0.E+03
4	Solids (suspended)	0.0.E+00	2.0.E+01	5.0.E+01	6.0.E+01	1.0.E+02	-8.0.E+02	-8.0.E+02
4	Nitrate	0.0.E+00	-3.0.E+01	7.0.E+01	4.0.E+01	5.0.E+01	-6.0.E+02	-6.0.E+02
4	Magnesium	0.0.E+00	7.0.E+00	1.0.E+01	1.0.E+01	6.0.E+00	-3.0.E+02	-3.0.E+02
4	Hydrocarbons to fresh water	0.0.E+00	-6.0.E+01	5.0.E+00	-7.0.E+01	-6.0.E+01	-1.0.E+02	-1.0.E+02
4	Oil (unspecified)	0.0.E+00	-5.0.E+01	4.0.E+00	-7.0.E+01	-5.0.E+01	-1.0.E+02	-1.0.E+02
4	Carbonate	0.0.E+00	-6.0.E+01	9.0.E+01	8.0.E+00	8.0.E+01	-2.0.E+02	-2.0.E+02
4	Nitrogenous Matter (unspecified, as N)	0.0.E+00	-4.0.E+01	2.0.E-01	-4.0.E+01	-2.0.E+01	-6.0.E+01	-6.0.E+01
4	Sodium sulphate	0.0.E+00	4.0.E+00	2.0.E+00	5.0.E+00	8.0.E+00	-8.0.E+01	-8.0.E+01
4	Ammonia	0.0.E+00	-1.0.E+01	2.0.E-01	-1.0.E+01	-9.0.E+00	-4.0.E+01	-4.0.E+01

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
4	Nitrogen organic bounded	0.0.E+00	-2.0.E+00	1.0.E+01	1.0.E+01	1.0.E+01	-7.0.E+01	-7.0.E+01
4	Chlorine (dissolved)	0.0.E+00	5.0.E-01	5.0.E-01	7.0.E-02	-4.0.E-01	-5.0.E+01	-5.0.E+01
4	Acid (calculated as H+)	0.0.E+00	4.0.E-03	2.0.E-03	-1.0.E+01	-1.0.E+01	-2.0.E+01	-2.0.E+01
4	Aluminum (+III)	0.0.E+00	8.0.E-02	5.0.E-01	-7.0.E-02	-8.0.E-01	-4.0.E+01	-4.0.E+01
4	Carbonate	0.0.E+00	-1.0.E+01	2.0.E+01	4.0.E+00	2.0.E+01	-5.0.E+01	-5.0.E+01
4	Methanol	0.0.E+00	-2.0.E+00	4.0.E-01	-2.0.E+00	-1.0.E+01	-1.0.E+01	-1.0.E+01
4	Nitrate	0.0.E+00	5.0.E-02	1.0.E-01	-4.0.E-01	-4.0.E-01	-2.0.E+01	-2.0.E+01
4	Sodium (+I)	0.0.E+00	4.0.E-01	1.0.E+00	2.0.E+00	3.0.E+00	-2.0.E+01	-2.0.E+01
4	Fluoride	0.0.E+00	1.0.E-03	8.0.E-04	-6.0.E+00	-6.0.E+00	-1.0.E+01	-1.0.E+01
4	Sulphate	0.0.E+00	-5.0.E+00	9.0.E+00	2.0.E+00	6.0.E+00	-2.0.E+01	-2.0.E+01
4	Phosphate	0.0.E+00	-2.0.E-01	2.0.E+00	2.0.E+00	2.0.E+00	-2.0.E+01	-2.0.E+01
4	Chemical oxygen demand (COD)	0.0.E+00	-7.0.E-01	2.0.E+00	1.0.E+00	3.0.E+00	-1.0.E+01	-1.0.E+01
4	Strontium	0.0.E+00	-1.0.E+00	1.0.E-01	-1.0.E+00	-3.0.E+00	-8.0.E+00	-8.0.E+00
4	Boron	0.0.E+00	2.0.E-01	2.0.E-01	2.0.E-01	-3.0.E-02	-1.0.E+01	-1.0.E+01

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
4	Total organic bounded carbon	0.0.E+00	-6.0.E-01	1.0.E+00	2.0.E-01	1.0.E+00	-9.0.E+00	-9.0.E+00
4	Sulfide	0.0.E+00	-1.0.E+01	2.0.E+01	1.0.E+01	2.0.E+01	-3.0.E+01	-3.0.E+01
4	Sulfide	0.0.E+00	-2.0.E+00	4.0.E+00	7.0.E-01	3.0.E+00	-9.0.E+00	-9.0.E+00
4	Ammonium / ammonia	0.0.E+00	-4.0.E+00	1.0.E+01	7.0.E+00	-2.0.E+00	-1.0.E+01	-1.0.E+01
4	Hydrogen peroxide	0.0.E+00	2.0.E-01	1.0.E-01	3.0.E-01	4.0.E-01	-4.0.E+00	-4.0.E+00
4	Copper (+II)	0.0.E+00	-7.0.E-01	1.0.E-01	-6.0.E-01	-9.0.E-01	-2.0.E+00	-2.0.E+00
4	Sulphite	0.0.E+00	7.0.E-02	6.0.E-02	7.0.E-02	-1.0.E-02	-3.0.E+00	-3.0.E+00
4	Chromium	0.0.E+00	-4.0.E-01	4.0.E-01	-4.0.E-02	-8.0.E-01	-2.0.E+00	-2.0.E+00
4	Hydrocarbons to sea water	0.0.E+00	-6.0.E-01	1.0.E+00	2.0.E-01	7.0.E-01	-2.0.E+00	-2.0.E+00
4	Lead (+II)	0.0.E+00	-2.0.E-01	1.0.E-01	-1.0.E-01	-1.0.E-01	-2.0.E+00	-2.0.E+00
4	Molybdenum	0.0.E+00	2.0.E-02	2.0.E-02	1.0.E-02	6.0.E-03	-1.0.E+00	-1.0.E+00
4	Nitrogen	0.0.E+00	8.0.E-02	-4.0.E-01	-3.0.E-01	-4.0.E-01	-8.0.E-01	-8.0.E-01
4	Oil (unspecified)	0.0.E+00	-4.0.E-01	6.0.E-01	1.0.E-01	5.0.E-01	-2.0.E+00	-2.0.E+00
4	Zinc (+II)	0.0.E+00	-3.0.E-01	3.0.E-01	2.0.E-02	-8.0.E-02	-1.0.E+00	-1.0.E+00

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
4	Manganese (+II)	0.0.E+00	-3.0.E-01	4.0.E-01	1.0.E+00	1.0.E+00	-2.0.E+00	-2.0.E+00
4	Hydrocarbons (unspecified)	0.0.E+00	-1.0.E-01	5.0.E-03	-1.0.E-01	-2.0.E-01	-7.0.E-01	-7.0.E-01
4	Biological oxygen demand (BOD)	0.0.E+00	2.0.E-02	7.0.E-02	8.0.E-02	1.0.E-01	-1.0.E+00	-1.0.E+00
4	Total organic bounded carbon	0.0.E+00	2.0.E-02	7.0.E-02	8.0.E-02	1.0.E-01	-1.0.E+00	-1.0.E+00
4	Phenol (hydroxy benzene)	0.0.E+00	-4.0.E-01	5.0.E-01	-3.0.E-02	5.0.E-01	-1.0.E+00	-1.0.E+00
4	Nickel (+II)	0.0.E+00	-2.0.E-01	2.0.E-01	7.0.E-03	1.0.E-01	-9.0.E-01	-9.0.E-01
4	Sodium chloride (rock salt)	0.0.E+00	4.0.E-02	3.0.E-02	6.0.E-02	1.0.E-01	-8.0.E-01	-8.0.E-01
4	Benzene	0.0.E+00	-3.0.E-01	5.0.E-01	5.0.E-02	5.0.E-01	-1.0.E+00	-1.0.E+00
4	Barium	0.0.E+00	-2.0.E-01	3.0.E-01	6.0.E-02	2.0.E-01	-8.0.E-01	-8.0.E-01
4	Toluene (methyl benzene)	0.0.E+00	-2.0.E-01	3.0.E-01	3.0.E-02	3.0.E-01	-6.0.E-01	-6.0.E-01
4	Arsenic (+V)	0.0.E+00	-1.0.E-01	2.0.E-01	2.0.E-02	2.0.E-01	-5.0.E-01	-5.0.E-01
4	Vanadium (+III)	0.0.E+00	3.0.E-03	3.0.E-03	1.0.E-04	8.0.E-04	-3.0.E-01	-3.0.E-01
4	Nitrite	0.0.E+00	9.0.E-04	1.0.E-03	-5.0.E-03	-5.0.E-03	-3.0.E-01	-3.0.E-01
4	Cyanide	0.0.E+00	-1.0.E-01	3.0.E-02	-1.0.E-01	1.0.E-01	-2.0.E-01	-2.0.E-01

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
4	Bromine	0.0.E+00	9.0.E-10	2.0.E-02	2.0.E-02	9.0.E-02	3.0.E-01	3.0.E-01
4	Magnesium ion (+II)	0.0.E+00	5.0.E-06	3.0.E-06	8.0.E-06	2.0.E-01	1.0.E+00	1.0.E+00
4	Hydrogen fluoride (hydrofluoric acid)	0.0.E+00	-2.0.E-03	9.0.E-01	9.0.E-01	1.0.E+00	8.0.E-01	8.0.E-01
4	Sodium hypochlorite	0.0.E+00	-3.0.E+00	2.0.E+01	1.0.E+01	1.0.E+01	9.0.E+00	9.0.E+00
4	Solids (dissolved)	0.0.E+00	3.0.E-01	3.0.E-01	-2.0.E-01	1.0.E+01	3.0.E+01	3.0.E+01
4	Potassium	0.0.E+00	-4.0.E+00	3.0.E+01	3.0.E+01	3.0.E+01	1.0.E+01	1.0.E+01
4	Organic compounds (unspecified)	0.0.E+00	-4.0.E+00	3.0.E+01	2.0.E+01	3.0.E+01	2.0.E+01	2.0.E+01
4	Biological oxygen demand (BOD)	0.0.E+00	-6.0.E+00	4.0.E+01	3.0.E+01	4.0.E+01	2.0.E+01	2.0.E+01
4	Phosphorus	0.0.E+00	-9.0.E-01	5.0.E+01	5.0.E+01	5.0.E+01	3.0.E+00	3.0.E+00
4	Adsorbable organic halogen compounds (AOX)	0.0.E+00	-1.0.E-01	6.0.E+02	6.0.E+02	6.0.E+02	-2.0.E+00	-2.0.E+00
4	Water (river water from technosphere, waste water)	0.0.E+00	-9.0.E+05	5.0.E+06	4.0.E+06	4.0.E+06	-5.0.E+06	-5.0.E+06
4	Water (river water from technosphere, rain water)	0.0.E+00	-4.0.E+04	1.0.E+07	1.0.E+07	1.0.E+07	1.0.E+07	1.0.E+07

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
5	Polycyclic aromatic hydrocarbons (unspecified)	0.0.E+00	-9.0.E-02	5.0.E-06	-9.0.E-02	-1.0.E-01	-2.0.E-01	-2.0.E-01
5	Thallium	1.0.E+00	1.0.E-01	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
5	Bromide	0.0.E+00	7.0.E-09	4.0.E-01	4.0.E-01	4.0.E-01	-3.0.E-07	-3.0.E-07
5	Beryllium	1.0.E+00	2.0.E-01	8.0.E-12	3.0.E-12	9.0.E-12	-1.0.E-10	-1.0.E-10
5	Molybdenum	2.0.E+00	2.0.E-01	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
5	Mercury (+II)	4.0.E+00	6.0.E-01	3.0.E-06	3.0.E-06	3.0.E-06	-5.0.E-07	-5.0.E-07
5	Chromium	4.0.E+00	7.0.E-01	4.0.E-01	4.0.E-01	4.0.E-01	-6.0.E-06	-6.0.E-06
5	Manganese (+II)	1.0.E+01	2.0.E+00	7.0.E-01	7.0.E-01	6.0.E-01	-6.0.E-02	-6.0.E-02
5	Strontium	2.0.E+01	3.0.E+00	9.0.E-08	2.0.E-06	2.0.E-06	3.0.E-07	3.0.E-07
5	Aluminum (+III)	0.0.E+00	1.0.E-05	4.0.E+00	4.0.E+00	4.0.E+00	5.0.E+00	5.0.E+00
5	Arsenic (+V)	3.0.E+01	4.0.E+00	5.0.E-03	5.0.E-03	4.0.E-03	-1.0.E-03	-1.0.E-03
5	Cobalt	8.0.E+01	1.0.E+01	1.0.E-01	1.0.E-01	7.0.E-02	-2.0.E-02	-2.0.E-02
5	Sulphate	0.0.E+00	7.0.E-05	5.0.E+01	5.0.E+01	5.0.E+01	-1.0.E-03	-1.0.E-03
5	Selenium	2.0.E+02	3.0.E+01	2.0.E-09	-2.0.E-09	-7.0.E-05	-7.0.E-05	-7.0.E-05

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
5	Cadmium (+II)	3.0.E+02	5.0.E+01	4.0.E-02	3.0.E-02	3.0.E-02	-1.0.E-02	-1.0.E-02
5	Barium	4.0.E+02	7.0.E+01	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
5	Fluoride	4.0.E+02	5.0.E+01	3.0.E+01	3.0.E+01	3.0.E+01	-3.0.E-02	-3.0.E-02
5	Phosphorus	1.0.E+02	2.0.E+01	2.0.E+02	2.0.E+02	2.0.E+02	-4.0.E-03	-4.0.E-03
5	Magnesium	0.0.E+00	3.0.E-04	3.0.E+02	3.0.E+02	3.0.E+02	-4.0.E-04	-4.0.E-04
5	Sulfide	0.0.E+00	4.0.E-04	3.0.E+02	3.0.E+02	3.0.E+02	-9.0.E-03	-9.0.E-03
5	Sulphur	8.0.E+02	1.0.E+02	1.0.E-04	3.0.E-04	5.0.E-04	-4.0.E-03	-4.0.E-03
5	Lead (+II)	8.0.E+02	3.0.E+02	8.0.E-03	8.0.E-03	8.0.E-03	-3.0.E-04	-3.0.E-04
5	Potassium (+I)	0.0.E+00	6.0.E-04	4.0.E+02	4.0.E+02	4.0.E+02	-1.0.E-02	-1.0.E-02
5	Antimony	1.0.E+03	1.0.E+02	5.0.E-10	-1.0.E-09	-3.0.E-05	-3.0.E-05	-3.0.E-05
5	Sodium (+I)	0.0.E+00	4.0.E-04	5.0.E+02	5.0.E+02	5.0.E+02	-1.0.E-02	-1.0.E-02
5	Zinc (+II)	1.0.E+03	3.0.E+02	7.0.E-01	7.0.E-01	7.0.E-01	-3.0.E-03	-3.0.E-03
5	Tin	1.0.E+03	8.0.E+02	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
5	Nickel (+II)	2.0.E+03	3.0.E+02	8.0.E-02	8.0.E-02	-2.0.E-01	-3.0.E-01	-3.0.E-01

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
5	Calcium (+II)	0.0.E+00	1.0.E-03	1.0.E+03	1.0.E+03	1.0.E+03	8.0.E+00	8.0.E+00
5	Chloride	0.0.E+00	-1.0.E+00	4.0.E+03	4.0.E+03	4.0.E+03	-3.0.E+01	-3.0.E+01
5	Titanium	1.0.E+04	2.0.E+03	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
5	Aluminum	1.0.E+04	3.0.E+03	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
5	Chlorine	2.0.E+04	3.0.E+03	5.0.E-07	-1.0.E-06	-2.0.E-06	-3.0.E-05	-3.0.E-05
5	Nitrogen	4.0.E+04	5.0.E+03	6.0.E-08	1.0.E-07	2.0.E-07	-2.0.E-06	-2.0.E-06
5	Copper (+II)	4.0.E+04	4.0.E+04	2.0.E-02	2.0.E-02	-1.0.E-02	-3.0.E-02	-3.0.E-02
5	Different pollutants	5.0.E+05	9.0.E+04	0.0.E+00	1.0.E-14	6.0.E-14	7.0.E-14	7.0.E-14
5	Carbon (unspecified)	2.0.E+06	3.0.E+05	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
5	Iron	4.0.E+06	1.0.E+06	7.0.E+01	6.0.E+01	6.0.E+01	1.0.E+02	1.0.E+02
6	Water	0.0.E+00	1.0.E+08	3.0.E+08	-1.0.E+09	-1.0.E+09	-2.0.E+10	-2.0.E+10
6	Water (river water)	0.0.E+00	2.0.E+08	3.0.E+08	-1.0.E+09	-1.0.E+09	-2.0.E+10	-2.0.E+10
6	Water (lake water)	0.0.E+00	-6.0.E+07	7.0.E+06	-2.0.E+08	-3.0.E+08	-1.0.E+09	-1.0.E+09
6	Inert rock	0.0.E+00	-1.0.E+07	5.0.E+05	-1.0.E+07	-3.0.E+07	-5.0.E+07	-5.0.E+07

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
6	Water (sea water)	0.0.E+00	2.0.E+05	4.0.E+05	-2.0.E+06	-2.0.E+06	-7.0.E+07	-7.0.E+07
6	Water (ground water)	0.0.E+00	-7.0.E+05	5.0.E+06	4.0.E+06	2.0.E+06	-9.0.E+06	-9.0.E+06
6	Hard coal (in MJ)	0.0.E+00	-3.0.E+05	2.0.E+04	-3.0.E+05	-7.0.E+05	-2.0.E+06	-2.0.E+06
6	Natural gas (in MJ)	0.0.E+00	4.0.E+04	7.0.E+04	9.0.E+04	1.0.E+05	-2.0.E+06	-2.0.E+06
6	Iron	0.0.E+00	-5.0.E+05	2.0.E+04	-5.0.E+05	-3.0.E+05	-8.0.E+05	-8.0.E+05
6	Lignite (in MJ)	0.0.E+00	3.0.E+04	3.0.E+04	6.0.E+04	6.0.E+04	-8.0.E+05	-8.0.E+05
6	Carbon dioxide	0.0.E+00	1.0.E+04	3.0.E+04	4.0.E+04	6.0.E+04	-5.0.E+05	-5.0.E+05
6	Bauxite	0.0.E+00	4.0.E+01	1.0.E+02	-1.0.E+05	-1.0.E+05	-2.0.E+05	-2.0.E+05
6	Copper	0.0.E+00	-4.0.E+04	6.0.E+00	-4.0.E+04	-5.0.E+04	-8.0.E+04	-8.0.E+04
6	Crude oil (in MJ)	0.0.E+00	-3.0.E+04	6.0.E+04	2.0.E+04	7.0.E+04	-1.0.E+05	-1.0.E+05
6	Peat (in MJ)	0.0.E+00	3.0.E+01	6.0.E+01	8.0.E+01	1.0.E+02	-2.0.E+04	-2.0.E+04
6	Oil sand (10% bitumen) (in MJ)	0.0.E+00	-6.0.E+03	1.0.E+02	-6.0.E+03	-4.0.E+03	-1.0.E+04	-1.0.E+04
6	Phosphate ore	0.0.E+00	1.0.E+03	-5.0.E+03	-4.0.E+03	-4.0.E+03	-1.0.E+04	-1.0.E+04
6	Pit Methane (in MJ)	0.0.E+00	-6.0.E+02	2.0.E+02	-7.0.E+02	-5.0.E+03	-1.0.E+04	-1.0.E+04

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
6	Potashsalt, crude (hard salt, 10% K2O)	0.0.E+00	5.0.E+02	-3.0.E+02	2.0.E+02	2.0.E+02	-1.0.E+04	-1.0.E+04
6	Manganese	0.0.E+00	-2.0.E+03	3.0.E+01	-2.0.E+03	-1.0.E+02	-4.0.E+03	-4.0.E+03
6	Zinc	0.0.E+00	-9.0.E+02	4.0.E+00	-9.0.E+02	-2.0.E+03	-2.0.E+03	-2.0.E+03
6	Oxygen	0.0.E+00	-6.0.E+02	3.0.E+01	-6.0.E+02	-1.0.E+03	-3.0.E+03	-3.0.E+03
6	Lead	0.0.E+00	-6.0.E+02	2.0.E+00	-6.0.E+02	-1.0.E+03	-1.0.E+03	-1.0.E+03
6	Bentonite	0.0.E+00	3.0.E+01	2.0.E+02	2.0.E+02	7.0.E+02	-3.0.E+03	-3.0.E+03
6	Coalbed methane (in MJ)	0.0.E+00	-1.0.E+02	2.0.E+00	-1.0.E+02	-9.0.E+02	-1.0.E+03	-1.0.E+03
6	Oil sand (100% bitumen) (in MJ)	0.0.E+00	-5.0.E+02	9.0.E+00	-5.0.E+02	-3.0.E+02	-9.0.E+02	-9.0.E+02
6	Fluorspar (calcium fluoride; fluorite)	0.0.E+00	9.0.E-01	2.0.E+00	-6.0.E+02	-6.0.E+02	-9.0.E+02	-9.0.E+02
6	Tight gas (in MJ)	0.0.E+00	-3.0.E+02	4.0.E+00	-3.0.E+02	-2.0.E+02	-6.0.E+02	-6.0.E+02
6	Sodium chloride (rock salt)	0.0.E+00	2.0.E+02	5.0.E+03	4.0.E+03	-4.0.E+03	-3.0.E+03	-3.0.E+03
6	Shale gas (in MJ)	0.0.E+00	-1.0.E+02	5.0.E+00	-1.0.E+02	-1.0.E+02	-3.0.E+02	-3.0.E+02
6	Nickel	0.0.E+00	2.0.E-01	7.0.E-02	4.0.E-01	-3.0.E+02	-3.0.E+02	-3.0.E+02

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
6	Sulphur	0.0.E+00	2.0.E+01	2.0.E+01	3.0.E+01	5.0.E+01	-3.0.E+02	-3.0.E+02
6	Phosphorus	0.0.E+00	-9.0.E+00	8.0.E+00	-1.0.E+00	-3.0.E+01	-5.0.E+01	-5.0.E+01
6	Uranium natural (in MJ)	0.0.E+00	7.0.E-01	6.0.E-01	9.0.E-02	-5.0.E-01	-6.0.E+01	-6.0.E+01
6	Shale	0.0.E+00	4.0.E-01	7.0.E-01	-1.0.E+00	-4.0.E+00	-5.0.E+01	-5.0.E+01
6	Chromium	0.0.E+00	-6.0.E-02	6.0.E-01	-2.0.E+00	-2.0.E+00	-4.0.E+01	-4.0.E+01
6	Gold	0.0.E+00	-4.0.E-01	6.0.E-05	-4.0.E-01	-3.0.E+01	-3.0.E+01	-3.0.E+01
6	Silver	0.0.E+00	-9.0.E+00	7.0.E-03	-9.0.E+00	-1.0.E+01	-2.0.E+01	-2.0.E+01
6	Stone from mountains	0.0.E+00	7.0.E+00	2.0.E+02	1.0.E+02	-1.0.E+02	-1.0.E+02	-1.0.E+02
6	Colemanite ore	0.0.E+00	6.0.E-01	3.0.E-01	9.0.E-01	1.0.E+00	-1.0.E+01	-1.0.E+01
6	Cobalt	0.0.E+00	2.0.E-05	1.0.E-05	2.0.E-05	-6.0.E+00	-6.0.E+00	-6.0.E+00
6	Natural pumice	0.0.E+00	1.0.E-02	1.0.E-01	-3.0.E-01	-6.0.E-01	-9.0.E+00	-9.0.E+00
6	Silicon	0.0.E+00	1.0.E+00	5.0.E-01	4.0.E+00	6.0.E+00	-1.0.E+01	-1.0.E+01
6	Magnesium	0.0.E+00	1.0.E+00	5.0.E-01	3.0.E+00	5.0.E+00	-1.0.E+01	-1.0.E+01
6	Molybdenum	0.0.E+00	2.0.E-02	8.0.E-02	-2.0.E-01	-3.0.E-01	-5.0.E+00	-5.0.E+00

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
6	Tin ore	0.0.E+00	1.0.E-01	6.0.E-02	2.0.E-01	2.0.E-01	-2.0.E+00	-2.0.E+00
6	Basalt	0.0.E+00	4.0.E-02	3.0.E-02	7.0.E-02	1.0.E-01	-2.0.E+00	-2.0.E+00
6	Titanium	0.0.E+00	-2.0.E-02	4.0.E-03	-1.0.E-02	-2.0.E-02	-7.0.E-01	-7.0.E-01
6	Platinum	0.0.E+00	9.0.E-07	7.0.E-07	1.0.E-06	-3.0.E-01	-3.0.E-01	-3.0.E-01
6	Heavy spar (BaSO4)	0.0.E+00	6.0.E-03	4.0.E-02	2.0.E-02	-1.0.E-02	-4.0.E-01	-4.0.E-01
6	Palladium	0.0.E+00	6.0.E-07	4.0.E-07	7.0.E-07	-2.0.E-01	-2.0.E-01	-2.0.E-01
6	Kaolin ore	0.0.E+00	2.0.E-02	2.0.E-02	6.0.E-02	3.0.E-01	-5.0.E-01	-5.0.E-01
6	Pyrite	0.0.E+00	-2.0.E-02	3.0.E-02	-1.0.E-02	3.0.E-01	9.0.E-01	9.0.E-01
6	Natural gas USA	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	4.0.E+00	2.0.E+01	2.0.E+01
6	Hard coal (in kg)	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	5.0.E+00	2.0.E+01	2.0.E+01
6	Ilmenite (titanium ore)	0.0.E+00	-5.0.E-01	3.0.E-01	-4.0.E-01	9.0.E+00	4.0.E+01	4.0.E+01
6	Magnesit (Magnesium carbonate)	0.0.E+00	-6.0.E+00	5.0.E+01	4.0.E+01	4.0.E+01	2.0.E+01	2.0.E+01
6	Crude oil (in kg)	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00	8.0.E+01	4.0.E+02	4.0.E+02

EC	Pollutant	E0	E1	E2	E3	E4	E5	E6
6	Gypsum (natural gypsum)	0.0.E+00	1.0.E+03	7.0.E+01	1.0.E+03	1.0.E+04	1.0.E+03	1.0.E+03
6	Dolomite	0.0.E+00	4.0.E+03	5.0.E+01	4.0.E+03	4.0.E+03	6.0.E+03	6.0.E+03
6	Magnesium chloride leach (40%)	0.0.E+00	3.0.E+01	4.0.E+02	4.0.E+02	5.0.E+02	3.0.E+05	3.0.E+05
6	Soil	0.0.E+00	1.0.E+04	3.0.E+05	3.0.E+05	4.0.E+05	3.0.E+05	3.0.E+05
6	Limestone (calcium carbonate)	0.0.E+00	-9.0.E+04	3.0.E+04	-7.0.E+04	4.0.E+05	1.0.E+06	1.0.E+06
6	Quartz sand (silica sand; silicon dioxide)	0.0.E+00	-2.0.E+04	5.0.E+05	5.0.E+05	5.0.E+05	5.0.E+05	5.0.E+05
6	Clay	0.0.E+00	-7.0.E+02	8.0.E+05	8.0.E+05	9.0.E+05	8.0.E+05	8.0.E+05
6	Natural Aggregate	0.0.E+00	1.0.E+05	7.0.E+05	8.0.E+05	8.0.E+05	8.0.E+05	8.0.E+05
6	Water (rain water)	0.0.E+00	-5.0.E+05	2.0.E+07	2.0.E+07	2.0.E+07	-1.0.E+07	-1.0.E+07
6	Air	0.0.E+00	-7.0.E+05	6.0.E+06	5.0.E+06	4.0.E+05	4.0.E+07	4.0.E+07