Make Lima Green Again!

Environmental Evaluation of Current and Alternative Treatments of Municipal Plastic Waste in Lima-Peru

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Universiteit Leiden

INDUSTRIAL ECOLOGY
INNOVATIVE BY NATURE

TU Delft

Make Lima Green Again!

Environmental Evaluation of Current and Alternative Treatments of Municipal Plastic Waste in Lima-Peru, using a Cradle-To-Grave Scope

Thesis Research Project

By

Diana Ita Nagy

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Cover photo: Recycled plastic pellets
Retrieved from: www.wtplastic.com (Withaya Intertrade Co. 2017)

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Executive summary

The amount of waste generated in cities around the world is expected to increase to 2.2 billion tons by the year 2025. This growth is closely related to the increase of urbanization, population and economic growth, especially in developing countries. Developing countries around the world are having problems coping with the increase in generated waste. This lack of management capacity results in risks and negative consequences to the environment and society.

Increasing the knowledge about the environmental impacts caused by inadequate disposal of solid waste could make municipalities and the government in developing countries more interested and pressured in finding more sustainable solutions. Life cycle assessment (LCA) is a method that fits perfectly when looking for evaluating potential impacts of different management options of municipal solid waste (MSW).

Among all the types of MSW, municipal plastic waste (MPW) is gaining more attention. Plastics have a high potential to be reinserted in the production chain of new products. Plastics are also prejudicial if disposed incorrectly in open dumps or water bodies, causing several negative impacts on the environment and society. The problematic of plastic waste is becoming a global issue and more actions need to be taken around it.

Peru is a country that has been affected by the increasing generation of MPW. Lima, Peru's capital, is the largest city regarding population, and is the biggest producer of MSW, with up to 40% of the country's total. The latest official report of environmental statistics in MSW in Peru mentions the generation of around 2,900 kilo tons of MSW in the year 2014, where 10% represented MPW. Also, the main destination of MSW in Peru are open dumps and landfills. In Lima, 75% of the collected MSW is disposed in landfills, and the remaining 25% is disposed in open dumps and water bodies.

LCA studies of MPW management in developing countries are not as common as they are for developed countries. Even though there is a big concern related to the lack of data to develop LCA in developing countries, there is a need to start studying these contexts.

The aim of this study is to evaluate potential solutions for MPW management in Lima, Peru. For this, first an inventory and systematic review of existing LCA studies of MPW and/or MSW management is performed. This first step provides available data, lessons learned and main conclusions, to be used and adapted for the second step, the development of an LCA of several management systems to deal with MPW in Lima. Thus, the main research question of this study is: **Based on existing LCAs of MPW and MSW management, and focused on the Peruvian context, what is the environmentally best waste management strategy for Lima (Peru) as an alternative to the current practice of open dumps and landfills?**

The first part of the study was based on a systematic review of selected LCA studies of MPW and/or MSW. For this, three steps were developed. First, an inventory of existing LCA was conducted using the Web of Science. Second, by specific selection criteria, only relevant studies were kept for further evaluation. The finally selected relevant studies added up to a total of 11 references. Third, those 11 relevant studies were further assessed following evaluation criteria, obtaining available data, lessons learned and main conclusions as a result.

Even though the selected studies showed some problems related to data availability and transparency, the systematic review permitted the collection of relevant data for the processes of collection, compaction, transfer, mechanical sorting and mechanical recycling of MPW. For the rest of processes and data gaps, Ecoinvent database v2.2 (2010) was used.

The second part of the study consisted on an environmental evaluation of alternatives for MPW management in Lima, Peru, and a comparison with the current management scenario. The functional unit of the study was "managing 1000 kg of generated MPW in Lima, Peru". Three scenarios were developed:

- Scenario SC1: baseline scenario representing the current situation in Lima, consisting on the disposal of 75% of MPW in landfills and 25% of MPW in open dumps.

- Scenario SC2: incineration scenario, consisting on the incineration of all MPW (100%) with energy recovery.

- Scenario SC3: recycling scenario, consisting on the mechanical recycling of 84.5% of MPW and incineration of 14.5% of unsorted plastics and losses from recycling.

The systematic review revealed that the more important parameters to be considered when performing LCA of MSW management are the method chosen to solve multifunctionality problems, the type of electricity mix assumed to be substituted and the assumed replacement ratio of recycled materials. Additionally, the case study also discovered other relevant key parameters, which were the assumed transport distance and the assumed landfill gas (LFG) collected. All these parameters were evaluated in the developed case study with sensitivity analyses.

Some of the evaluated studies performed sensitivity analysis of the type of electricity mix assumed and the replacement ratio assumed, but none of the studies evaluated the sensitivity of the results to the method chosen to solve the multifunctionality problem. All of the evaluated studies only chose the substitution method to solve multifunctionality.

For the case study performed in this report, the economic allocation method was applied first to solve the multifunctionality problem. Later, as part of the sensitivity analysis, and considering that all the selected studies applied the substitution method, this method was also applied in the case study. This allowed the comparison of the effects of both methods in the final results on the three scenarios.

The comparison of both methods to solve multifunctionality showed that the results heavily depended on the selected method. In the case of economic allocation, the characterization results were all represented by positive numbers. During this type of allocation method, the prices of the wastes and goods play an important role as together with the size of these functional flows, they constitute the basis for the partitioning of the impacts among the functional flows.

When substitution was performed instead of economic allocation to solve multifunctionality, most of the environmental impacts of scenario SC3 were represented by negative numbers. This is because the substitution method solves multifunctionality by subtracting the avoided burdens of replaced products. These results with negative numbers were similar to the ones observed in the evaluated case studies, were also the substitution method was used and negative numbers appeared especially for the recycling scenarios.

The performed sensitivity analyses showed that the case study results depend on modelling decisions and the main assumptions made during the study. First, the baseline characterization results, under all the assumptions made and using economic allocation, showed the recycling scenario SC3 as the most preferable option for all the impact categories. However, the evaluation of the sensitivity of these results to the allocation method, type of electricity mix assumed, replacement ratio assumed, transport distances and the amount of LFG collection assumed, showed that the results were subject to change when assumptions were modified and that the permanence of the recycling scenario as the best option was not maintained for all the impact categories.

The sensitivity analysis of the assumed transport distances showed that an increment on the distances highly influence the amount of environmental impacts. During the systematic review, the collection and transport stages were mentioned as not significant. However, the contribution analysis in the case study showed that the impacts of the collection and transport stages together were responsible for around 50% for most of the impact categories. An increase of 10 km in the transport distance was evaluated by a sensitivity analysis in SC3. This analysis showed that with this increase, the scenario SC3 became less preferable to scenario SC2 in five categories and less preferable to scenario SC1 in one category.

These results on the effects of transport distances mean that it is not only important to improve the MPW management strategy in Lima, but also the systems of collection and transport of the MSW. More efficient systems of collection and transport that could reduce the distances travelled would mean a reduction in the impacts on the environment. This improvement in the collection and transport systems should be part of the main decisions taken by the authorities in Peru.

Another important finding of this study was the sensitivity of the results of scenario SC1 when the amount of LFG assumed to be collected and flared was changed. To resemble the Peruvian situation, for the case study it was first assumed that the collection of LFG was 0%. This assumption was evaluated by increasing the percentage of collected LFG to 47%. This assumption revealed that an increase on the collection of LFG could reduce the impacts of photochemical oxidation and climate change. Thus, it is important to introduce systems of LFG collection in sanitary landfills, which would reduce the amount of GHG emissions.

It is important to mention that, even though in the case study open dumps were included as part of the scenario SC1, they should be avoided by all means. Open dumps produce enormous amount of impacts on the environment and to society, including the increase of soil degradation, flooding risks, pollution of water bodies and air, among others. Also, part of the social impacts of open dumps are the presence of waste scavengers, which are often children and low-income inhabitants that pick up recyclable materials without any type of personal protective equipment, risking their safety and health.

All these environmental and social impacts of open dumps have not been considered in this LCA, which means that the actual impacts of disposing MPW in open dumps were underestimated in this study. However, these impacts are visible by the Peruvian community and are a reality for the country. Any efforts to improve the MPW management of the country must also aim at eliminating the use of open dumps as disposal spaces.

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First of all, I would like to thank my parents and siblings. The main reason why I've got this far is because of their constant support and love. Thank you for having been there for me unconditionally all this time, for believing in me, for inspiring me.

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I dedicate this thesis to my mom, I know that she is deeply proud of her little daughter.

Diana

Abbreviations

ALCA	Attributional Life Cycle Assessment
CHP	Combined Heat and Power
CLCA	Consequential Life Cycle Assessment
FU	Functional Unit
GHG	Greenhouse Gases
HDPE	High Density Polyethylene
IF	Incineration Facility
INEI	Instituto Nacional de Estadística e Informática
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LDPE	Low Density Polyethylene
LF	Landfill
MINAM	Ministerio Nacional del Ambiente
MPW	Municipal Plastic Waste
MRF	Material Recycling Facility
MSW	Municipal Solid Waste
NAMA	Nationally Appropriate Mitigation Action
NIR	Near Infra-red
PE	Polyethylene
PET	Polyethylene Terephthalate
PP	Polypropylene
PS	Polystyrene
PSF	Programas de Separación en la Fuente
PVC	Polyvinyl Chloride
SIGERSOL	Sistema de Información para la Gestión de Residuos Sólidos
WoS	Web of Science

Glossary

The definitions indicated below are obtained from the Handbook on Life Cycle Assessment by Guinée et al. (2002).

alternative: one of a set of product systems studied in a particular LCA, e.g. for comparison (note: some LCA steps are carried out for all alternatives together (e.g. selection of impact categories), while others are repeated for each alternative (e.g. characterisation)

background system/process: a system or process for which secondary data, viz. databases, public references, estimated data based on input-output analysis, are used in an LCA baseline

category indicator: a quantifiable representation of an impact category, e.g. infrared radiative forcing for climate change

characterization: a step of Impact assessment, in which the environmental interventions assigned qualitatively to a particular impact category (in classification) are quantified in terms of a common unit for that category, allowing aggregation into a single score: the indicator result; these scores together constitute the environmental profile

characterisation factor: a factor derived from a characterisation model for expressing a particular environmental intervention in terms of the common unit of the category indicator, e.g. $POCP_{methanol}$ (photochemical ozone creation potential of methanol)

characterisation method: a method for quantifying the impact of environmental interventions with respect to a particular impact category; it comprises a category indicator, a characterisation model and characterisation factors derived from the model

classification: a step of Impact assessment, in which environmental interventions are assigned to predefined impact categories on a purely qualitative basis

completeness check: a step of the Interpretation phase to verify whether the information yielded by the preceding phases is adequate for drawing conclusions in accordance with the Goal and scope definition

consistency check: a step of the Interpretation phase to verify whether assumptions, methods and data have been applied consistently throughout the study and in accordance with the Goal and scope definition

contribution analysis: a step of the Interpretation phase to assess the contributions of individual life cycle stages, (groups of) processes, environmental interventions and indicator results to the overall LCA result (e.g. as a percentage)

economic flow: a flow of goods, materials, services, energy or waste from one unit process to another; with either a positive (e.g. steel, transportation) or zero/negative (e.g. waste) economic value

elementary flow: matter or energy entering or leaving the product system under study that has been extracted from the environment without previous human transformation (e.g. timber, water, iron ore, coal) or is emitted or discarded into the environment without subsequent human transformation (e.g. or noise emissions, wastes discarded in nature) see also: environmental intervention

emission: a chemical or physical discharge (of a substance, heat, noise, etc.) into the environment, considered as an environmental intervention

environmental impact: a consequence of an environmental intervention in the environment system

environmental process: a physical, chemical or biological process in the environment system that is identified as part of the causal chain linking a particular environmental intervention to a particular impact, e.g. pollution leaching or bioaccumulation; for a given impact category, the environmental processes together form the environmental mechanism

foreground system/process: a system or process for which primary, site-specific data are used in an LCA, for whatever reason

functional unit: the quantified function provided by the product system(s) under study, for use as a reference basis in an LCA, e.g. 1000hours of light (adapted from ISO)

impact category: a class representing environmental issues of concern to which environmental interventions are assigned, e.g. climate change, loss of biodiversity

indicator result: the numerical result of the characterisation step for a particular impact category, e.g. 12 kg CO_2-equivalent for climate change

inventory table: the result of the Inventory analysis phase: a table showing all the environmental interventions associated with a product system, supplemented by any other relevant information (adapted from ISO)

midpoint approach: (problem-oriented approach) definition of category indicators close to environmental interventions

multifunctional process: a unit process yielding more than one functional flow, e.g. co-production, combined waste processing, recycling

multifunctionality and allocation: a step of the Inventory analysis in which the inventory model is refined and the input and output flows of multifunctional processes are partitioned to the functional flows of those processes

normalisation: a step of Impact assessment in which the indicator results are expressed relative to well-defined reference information, e.g. relative to the indicator results for global interventions in 1995

normalisation factor: the reciprocal of the indicator result for a particular impact category and reference system; used in the normalisation step

sensitivity and uncertainty analysis: a step of the Interpretation phase to assess the robustness of the overall LCA results with respect to variations and uncertainties in the methods and data used

system boundary: the interface between a product system and the environment system or other product systems

transparency: open, comprehensive and understandable presentation of information

unit process: the smallest portion of a product system for which data are collected in an LCA

1. Introduction

In the year 2012, the total amount of municipal solid waste globally generated in cities was around 1.3 billion tons, expecting to increase to 2.2 billion tons by the year 2025 (Hoornweg and Bhada-Tata 2012). Also, cities around the world are expected to keep growing every year due to the increase of population, urbanization and economic growth, especially in developing countries (Laurent et al. 2014a).

Whereas most European countries are good examples of adequate ways of waste management, developing countries have problems coping with the rapidly increasing amount of waste generated. Inefficient waste management causes risks and negative consequences to the environment and society, such as contamination of groundwater and water bodies due to leachate, and air pollution from uncontrolled waste burning.

Waste management is known as a complex activity, involving a wide range of stakeholders and comprising many parameters to be considered at once (Ekvall et al. 2007). Within these parameters, the evaluation of environmental impacts of different solutions for waste management is required. The lack of knowledge of the impacts generated by inadequate disposal of solid waste, makes municipalities less interested in finding more sustainable solutions.

To evaluate the potential impacts of different ways of disposing solid waste, the Life Cycle Assessment (LCA) method is used. LCA is a method broadly used to evaluate waste management strategies from an environmental perspective. It helps evaluating suitable options for waste management (Laurent et al. 2014a), by quantifying the potential environmental impacts related to the waste management system (Ekvall et al. 2007). This decision-supporting tool also provides valuable inputs that help practitioners and stakeholders to identify hot-spots in their waste management alternatives (Laurent et al. 2014a).

Another attribute of LCA, is its ability to identify environmental benefits that could be possibly obtained through different management processes. The energy obtained during waste incineration could diminish the use of other fossil fuel based energy sources (oil, natural gas). Also, the use of recycled materials during the production of goods, could reduce the extraction of virgin materials, and the impacts related to it. (Cherubini et al. 2009).

Currently, several published studies related to LCA and municipal solid waste (MSW) management can be found, being mostly concentrated in Europe. From these studies, we can observe that there is a strong dependence on local conditions to define the best practice for MSW management, which affects the composition of waste, the local energy system, the consumer behaviour and other aspects. This dependence does not allow practitioners or policy developers to generalize LCA results from other studies to their own problem context (Laurent et al. 2014a).

LCA studies of waste management in developing countries are not as common as they are for western countries. Therefore, there is a need of developing LCA in these countries to capture local and specific conditions for the different MSW management options available, identifying critical problems, and facilitating the proposal of viable options. Even though data availability is a big concern for the development of these studies, it is necessary to start studying these contexts (Laurent et al. 2014a) by using existing LCA studies as a base.

Within the different types of MSW, plastic waste is gaining more and more attention, because of its almost non-existent biodegradation capability, and its high potential to be reinserted into the production chain. Plastics are stable products that could be separated, recycled and used as a replacement of virgin materials, known as "upcycling", or as fuel to obtain electricity and heat, known as "downcycling".

Also, plastic waste is becoming a global problem, and needs to be taken more seriously. Every year, more plastic debris goes directly, or indirectly, to the ocean, transforming into small fragments of micro plastics that accumulate in specific zones. Hence, an improved waste management, treatment and disposal, especially in countries where the production and use of plastic is rapidly increasing, is needed to prevent plastics from entering the oceans (UNEP 2011).

One developing country that has been affected by the increasing generation of municipal waste, and specifically of plastic waste, is Peru. The city that produces the largest quantity of municipal waste (up to 40% of the country's total) is Lima, the capital and most populated area, located in the coastal region. LCA studies focusing on MSW, and specifically on mixed plastic waste, have not been performed in Peru so far. This study is the first effort to evaluate and identify the different possibilities of mixed plastic waste management from an environmental perspective.

2. Problem definition

Peru, as many other developing countries with emerging economies, shows an important increase on municipal waste generation. The latest official report of environmental statistics in solid waste in Peru (INEI 2015) mentions that in 2014, approximately 2,900 kilo tons of municipal solid waste (MSW) were generated in Lima province, with an average generation of 0.4 ton/hab/year or 1 kg/hab/day. The Peruvian Ministry of Environment (MINAM, for its acronym in Spanish) mentions that one of the main components are plastics with 10% of the total waste generated (MINAM 2013a). This means that around 290 kilo tons of municipal plastic waste (MPW) is generated annually in Peru's capital.

However, MSW is still managed in a poor way in Peru. The main destinations of MSW in Peru are uncontrolled open dump (Figure 2-1) and landfilling. Landfilling, as an option of waste management, is always discouraged because of the generation of pollutants and leachate, and because of land scarcity as a result of advancements in urbanization (Othman et al. 2013). These negative impacts get aggravated when uncontrolled open dumps are used instead of disposal areas. Open dumps cause water contamination, soil and air pollution, spread of diseases, release of gases and bad odours, among other negative impacts.

Figure 2-1: Uncontrolled open dump in Lima, Peru (El Comercio 2015)

Diminishing landfill and open dumps use, by increasing recycling and incineration of waste, should be understood as an economic and environmental opportunity. However, the General Law of Solid Waste N°27314 (Congreso de la Republica (Republic Congress) 2000), demands the disposal of MSW in landfills, including recyclable materials like plastic.

Also, there is a lack of information related to the potential negative impacts of landfill and open dump use, and a comparison with the impacts of recycling and/or incineration techniques. The Peruvian community and policy makers are not aware of the environmental consequences of disposing MSW and MPW in open dumps and landfills.

Plastics in open dumps and landfills have a slow degradation process, and will remain intact for long periods of time. Considering that plastics are materials with the potential of being recycled and/or incinerated, and that they represent the second largest amount of waste in MSW in Peru, it is important to evaluate and show the benefits of alternative management techniques. This could motivate citizens and decision makers to accelerate the transition to a more environmentally friendly waste management scenario.

This study aims to identify better alternatives for municipal plastic waste management from an environmental point of view and under which circumstances. Also, the study evaluates the potential negative impacts of landfill and open dumps for the Lima context.

2.1 Research questions

Based on the aim of the study, the following main research question is developed:

Based on existing LCAs of MPW and MSW management, and focused on the Peruvian context, what is the environmentally best waste management strategy for Lima (Peru) as an alternative to the current practice of open dumps and landfills?

To answer the main research question, the following sub-questions are used as a guide:

- What can be learned from existing LCAs of plastic and MSW management for a better elaboration of an LCA of MPW management options in Lima, Peru?
- What are the key parameters in these existing LCAs and should – and if so, how - these parameters be changed for the Peruvian context?
- Taking an environmental life cycle perspective, what is the environmental preference hierarchy of MPW management options for the Lima context as alternative to the current practice of open dumps?
- How can the application of LCA of waste management help decision makers in choosing better management options?

In this study, the inventory and analysis of existing LCAs of MPW and MSW management is performed to develop an adapted LCA of MPW management strategies for the Lima context. For this, available data, lessons learned and main conclusions on the existing LCAs of MPW and/or MSW are identified.

Following this, an evaluation using LCA of the current situation and scenarios contemplating different alternatives for plastic waste management in Lima is developed. This assessment ends with the quantification of the potential environmental impacts caused by different management alternatives of MPW, which are compared to the current situation in Lima, which is using open dumps and landfill as a destination for MPW.

3. Current and alternative waste management systems for Peru

3.1 Municipal plastic waste

Nowadays, plastics are part of our lives, being presented in different ways, shapes and functions. In households, plastics are commonly used for packaging, covering, containers, bags and films, and represent between 10% and 20% of the total amount of waste (WASTE 2015). Thermoplastics are the type of plastics more consumed because of their properties, and they represent a big amount of the MPW (Al-Salem et al. 2009).

The type of plastics that can be found in MSW include polyethylene terephthalate (PET) and high density polyethylene (HDPE) mostly in plastic bottles or hard plastic items; low density polyethylene (LDPE) mostly in soft plastic materials and film; and polystyrene (PS) and polypropylene (PP) as food packaging materials (Rigamonti et al. 2014). The composition of each plastic product depends on their uses and required properties.

3.2 Municipal solid waste characterization in Peru

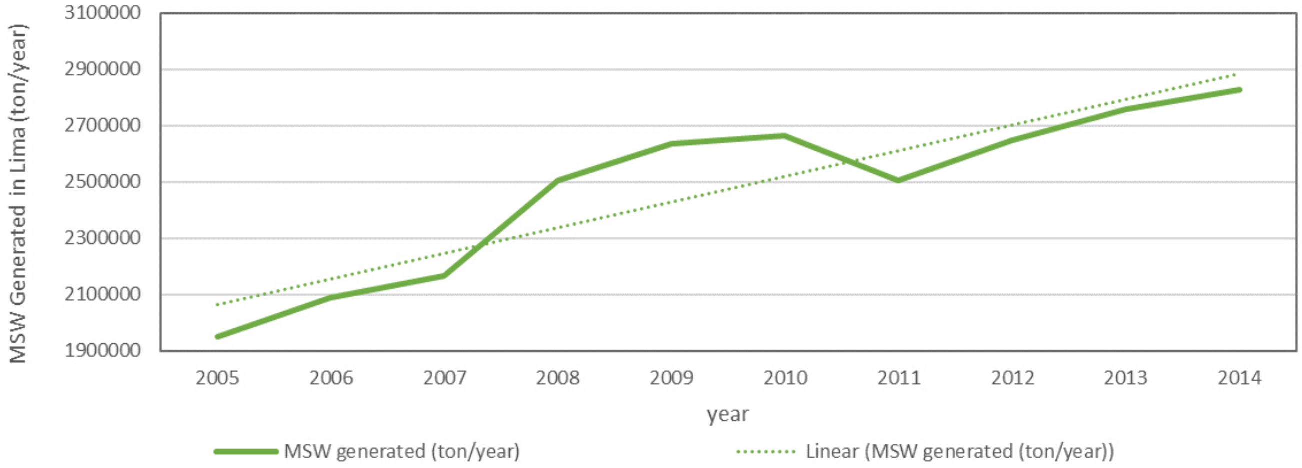
The MINAM developed a report of the "Diagnosis of Solid Waste in Peru", including an analysis of the composition and management of MSW in Peru (MINAM 2013b). This report indicates that the amount of MPW represents between 8% and 12% of the total MSW generated in Peru (MINAM 2013a). Also, Lima Metropolitan Area is the biggest waste generator, being responsible of 41% of the total urban waste generated in Peru. It is important to mention that Lima contains 40% of Peru's population.

3.2.1 MSW generation

Lima Province, in 2014, generated 2'893,187 tons of MSW, while in 2013 the amount generated was 2'759,701 tons, which means an increase of 2.5% (INEI 2015). Municipal waste, as observed in Figure 3-1, has been increasing in the last years, with an annual average of 1.4% (MINAM 2013a). The average of MSW generation per capita in urban zones in Lima is 0.954 kg/hab/day by 2012, which would mean 7,926 ton/day by 2012

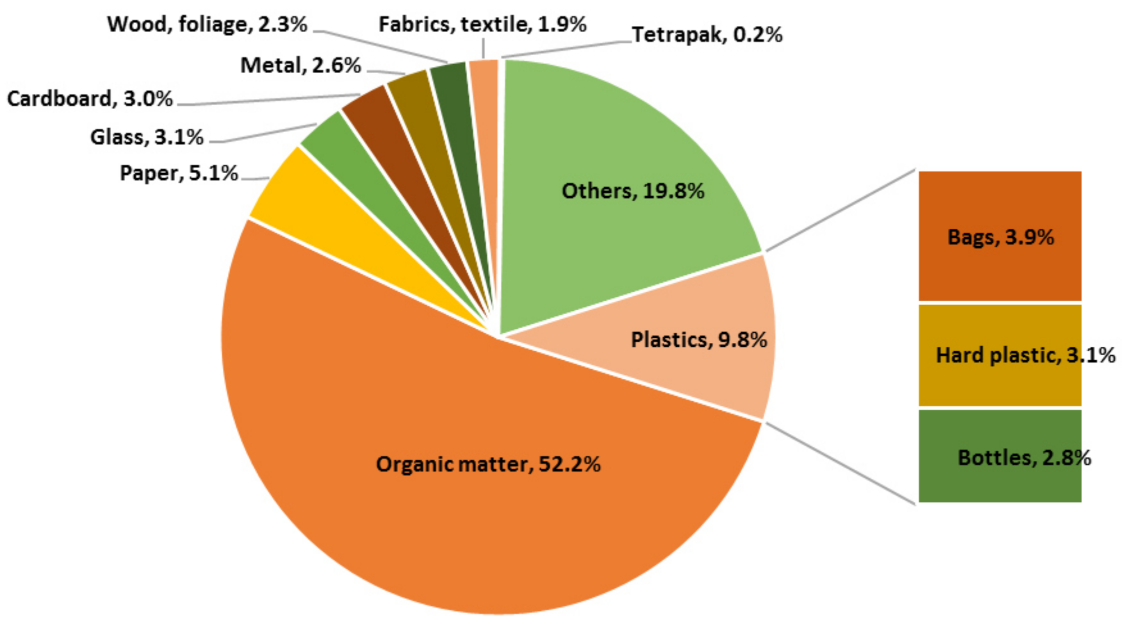
(MINAM 2013a). A representation of the current growth of MSW per year in Lima is shown in Figure 3-1.

Figure 3-1: MSW generation growth in Lima, Peru (2005-2014) – INEI 2015



The composition of the municipal waste is shown in Figure 3-2, where the municipal solid waste composition is illustrated by the weighted average of the country (MINAM 2013a).

Figure 3-2: Composition of MSW generated in urban areas of Peru (2012) – MINAM 2013



According to this chart, around 10% of the total MSW generated corresponds to MPW. This amount represents a volume of material able to be exploited and reutilized. However, this material is currently landfilled, disposed in open dumps, streets or in nature.

The Information System for Solid Waste Management (SIGERSOL for its acronym in Spanish) provides information of MSW characterization per municipality. For the case of Lima, 48 municipalities provide information related to the type of plastics collected in their area. On average, the percentage of waste corresponding to plastics is 10.6%, and from this, 25.3% are PET bottles, 31.3% are hard plastics and 43.5% are plastic bags (SIGERSOL 2015). This percentages are similar to the ones observed for the entire country (Figure 3-2).

3.2.2 MSW collection and final disposal

In Peru, there are still cities, towns and districts where there is no collection of waste at all, and the generated waste is just disposed in the surroundings, like streets, illegal dumps or water bodies, without any management. On the other hand, the waste that is actually collected by each municipality, is disposed either in landfills or open dumps, depending on the availability of both (MINAM 2013a).

Lima has a high collection rate of municipal waste, with a 90% coverage by 2012, only considering the urban areas. The waste collection coverage of the whole country was around 65% by 2013 (MINAM 2013a). In Lima, the collection of waste occurs mostly daily, increasing the environmental impact of waste management by generating a bigger need of fossil fuels requirement for trash trucks, and other resources (staff, equipment, logistics) (INEI 2015). In western countries, for example, waste collection occurs most of the time only once a week, without major problems of waste accumulation on houses and streets.

Table 3-1: Waste collection frequency in Lima, Peru

Year	City	Municipalities*	Daily	Every other day
2013	Lima	49	44	5
	%	-	90%	10%
2014	Lima	49	48	1
	%	-	98%	2%

* Municipalities that collect waste within Lima
Source: Compilation based on INEI 2015

As for disposal, the General Law of Solid Waste N°27314 (Congreso de la Republica 2000), demands all municipalities to do the disposal of solid waste in Peru in landfills. Nevertheless, there are only eight (08) landfills in Peru, which is by far not enough to handle the daily amount of generated waste. From these eight landfills, four are in Lima, collecting around 75% of the urban solid waste generated. The rest is disposed in unauthorized open dumps just outside the city and water bodies, eventually ending up in the ocean (MINAM 2013a; INEI 2015).

3.3 Plastic waste management

Plastic waste is a material that can be recycled. The main categories of plastic recycling include the primary recycling or re-extrusion, secondary or mechanical recycling, tertiary or chemical recycling and, finally, incineration with energy recovery. These methods have different requirements, advantages and disadvantages, that could adjust better to different realities, locations and applications (Al-Salem et al. 2009).

One of the main advantages and, at the same time, main disadvantage of plastics is their chemical stability over time. This property makes materials useful for different applications but also makes them hard to degrade in landfills, water bodies and nature, where they will stay for years without decomposing. In addition to that, when they start decomposing, plastics release harmful chemicals that could destroy natural resources and affect ocean life. The reduction of plastics in landfills, open dumps and nature, by reusing, recycling and incineration will also reduce the negative impacts on the environment (Al-Maaded et al. 2012).

Currently, Peru is trying to improve the waste management system around the country. For this, there are several projects and initiatives related to better management of collected waste. However, there is a lack of knowledge related to the environmental impact of the options for waste management, including MPW management.

Plastic recycling is a practice that is still not well developed in the country, and only occurs for small fractions of plastic waste, mostly PET bottles, in some specific areas. Also, the market for recuperated plastics is currently under development in Lima. One of the main constraints is the sorting and handling issues for mixed plastics, because plastic fractions are difficult to sort and separate into marketable highly pure fractions (Foster 2008). Another constraint is the lack of incentive from the government to encourage municipalities, companies and inhabitants to participate in the existing recycling schemes.

For this study, the plastic mix includes all MPW generated, mainly related to plastic containers and packaging materials. The analysis includes flexible and rigid plastics from different polymer compositions and colours.

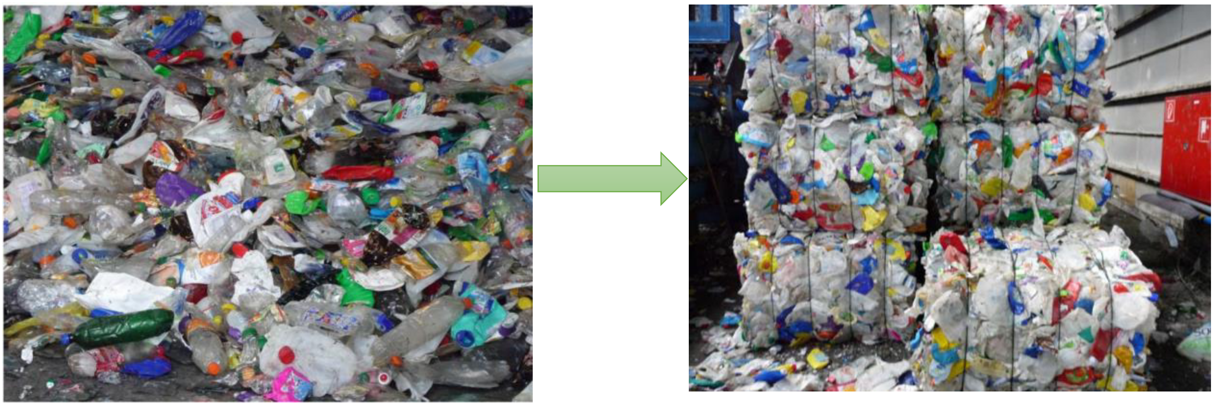
3.3.1 Sorting and separation

MPW is hard to manage since it is normally found as a mix of different plastic types, shapes and physical characteristics. There are techniques available to sort plastic waste according to their characteristics and composition. One of these is sorting by their density, which can be complicated since plastic fractions have similar densities (i.e. from 0.91 to 0.96 g/cm^3) (Al-Salem et al. 2009). Another technique is near infra-red (NIR) sorting, which is an optical sorting technology that separates plastics by their polymers (Shonfield 2008).

The main difference between these two techniques is that density separation is less flexible but with a higher recovery rate, and NIR separation can sort more different types of plastic fractions, but with a lower recovery rate. Which technology to choose will depend on the availability of the technology, and markets available for the recovered products (Shonfield 2008).

According to Al-Salem et al. (2009), sorting is the most relevant stage in a recycling scheme. The operating costs of sorting, however, are also one of the main constraints of adopting recycling techniques for waste management.

Figure 3-3: Example of plastic sorting results – Shonfield 2008



Before sorting of plastic mix

After sorting of plastic mix (HDPE bales)

3.3.2 Mechanical recycling

After the sorting process, the separated plastic fractions could be part of a mechanical recycling process, that consists mainly of cleaning, reduction of size of the plastics, melting and extrusion into new pellets (Lazarevic et al. 2010). It is important to mention that, mechanical recycling of plastic waste is only effective if plastic purity is high after the sorting and separation process (Dodbiba et al. 2008).

This technique is a process that ends with the formation of compounds (pellets) to be reused in the manufacturing of new plastic products (Perugini et al. 2005). This type of recycling has to be performed on single polymers (PE, PET, PP, PS) previously separated in clean fractions. The separation of plastics in single polymers could be difficult if the materials are highly heterogenous or the collected waste is contaminated with other products (e.g. aluminium foil) (Al-Salem et al. 2009).

In Peru, as many other developing countries, recycling of plastic waste is not as developed as in western countries, and is carried out mostly by people with low incomes. These people collect plastic waste, mostly PET bottles, to sell them and earn a small revenue from it. This informal sector keeps increasing and gaining importance, that is currently being used as a starting point for improving plastic recycling (WASTE 2015). Some municipalities in Lima are working on making this "informal recycling sector" a formal one, by grouping them in working zones and providing them with benefits (special clothing, training, health insurance). Also, some municipalities are including the "informal recyclers" into their programs of separation at source (PSF, for its acronym in Spanish). The PSF programs include the separation at the source and later recuperation of waste materials (MINAM 2013a).

Figure 3-4: Formalized recycler in Lima, Peru

3.3.3 Incineration

Another way of recycling plastic waste is by converting them into electricity and heat. Incineration of plastic waste with energy recovery is especially beneficial when they cannot be converted by mechanical recycling into new plastic pellets, because of contamination or deterioration of the polymers' quality (Perugini et al. 2005).

In this case, the plastic mix that enters the process is not separated. The energy recuperated after the incineration is then used for producing electricity. Heat is also a sub product of this process, and it could be recovered in order to maximize the benefits of it (Shonfield 2008).

3.3.4 Landfill

Landfilling is considered as the least preferable alternative to waste management, especially for recyclable wastes, such as plastics. A landfill is a specialized facility utilized for proper disposal of wastes, with specific techniques to prevent environmental emissions.

In Peru, the type of landfill used is a sanitary landfill. This type consists of placing layers of waste followed by covering material to avoid scavenging. It also includes a collection scheme for the leachate produced at the bottom. Lastly, at the closure of the landfill, an impermeable cover is added to avoid water infiltration and leachate production (Diaz 2004).

Landfilling impacts are related to the chemical compounds released to the environment, normally during long periods of time. Because of that, the amount of pollutants cannot be measured in real life and needs to be modelled (Doka 2009a). Thus, landfill emissions are modelled for two periods of time, short term emissions (up till 100 years) and long term emissions (from 100 till 60’000 years) (Doka 2009a).

4. Analytical framework and method

The approach taken to answer the research question starts with an extensive literature and systematic review of existing LCA of plastic waste and/or MSW management. These scientific articles are reviewed to obtain useful data that could be directly used or adapted to the Lima context.

Another important goal is to evaluate lessons learned, and main conclusions, forming the base for the development of an LCA of MPW management for Lima. During this review, key parameters that need to be adapted according to specific location characteristics are identified.

Following this step, an adapted and validated LCA for Lima of different MPW management options is developed. This evaluation includes a comparison between the current situation and better management options, with the purpose to define the best waste management strategy for Lima in terms of environmental impacts.

4.1 Systematic review of LCA studies

LCA studies of plastic waste and MSW management systems are widely available. Most of these studies are related to developed countries, where innovative solutions for MSW management are frequently driven by policies and incentives to minimize landfilling and negative environmental impacts. These studies concluded that landfilling is the least environment-friendly alternative in the waste hierarchy. However, there is no consensus on which alternative is the most optimal since it depends on the local situation. Local conditions affect the waste composition, treatment efficiency and electricity supply mix, and the quality of plastic waste, which in turn affects the benefits of mechanical recycling (Laurent et al. 2014a). Thus, LCA is used to determine waste hierarchies considering a specific context and local factors.

One way of taking advantage of these studies is to combine the results obtained through a systematic review (Lifset 2012). A systematic review of studies enables the compilation of key parameters that are found commonly among evaluated studies.

Since LCA studies are not completely homogenous in terms of their research designs, it is not easy to use straightforward statistical techniques to analyse the results obtained by them (Lifset 2012). Also, recognized guidelines or protocols to conduct or report systematic reviews in LCA are currently not available (Zumsteg et al. 2012). For this reason, there is a need to define a list of evaluation criteria to develop the analysis of the selected studies.

To develop an appropriate systematic review of available LCA studies, three steps are going to be developed. These steps are described below and are guided by the systematic review of Villanueva and Wenzel (2007) on LCA of paper waste management. First, an inventory of existing LCAs is conducted, using the Web of Science supplied by Thomson Reuters ISI. Second, by defined literature selection criteria, only pertinent studies are kept for evaluation. Third, those selected studies are further assessed by a list of evaluation criteria and available data, results and main conclusions are compiled.

4.1.1 Inventory of existing LCA of MSW management

This study starts with the review of existing studies in LCA of plastic waste and/or MSW management. For this, an exhaustive search of published articles in scientific journals with topics closely related to LCA of plastic waste management is done. The search is conducted in an international base, considering only studies reported in the English language.

The bibliometric analysis is conducted using the Web of Science (WoS) as a search engine. The search is conducted in "all databases", utilizing the keywords [Life Cycle Assessment], [plastic*], [waste] and [management] for the period 2006-2016 (accessed on 18 October 2016). This search resulted in 246 references.

In relation to the time span of the articles, one of the main characteristics on waste management systems, that could affect the results of an LCA study, is the type of technology selected. Every year, all different technologies available for processing plastic waste are renovated and improved. For that reason, articles more than ten years old were discarded.

The abstracts of the selected references were then evaluated to discard those without connections to Life Cycle Assessment in Waste Management. After the abstract evaluation, 52 references have been considered for further analysis. The list of these references is shown in Appendix A.

The selected studies were mostly performed to support decision makers during the selection of best practices for plastic waste management. The case studies were developed and evaluated under specific scenarios, for a local, regional or national scale. The options considered in these studies are mainly landfill, recycling and incineration with energy recovery.

4.1.2 Literature selection criteria

To select studies that are connected to plastic waste and/or MSW management, and that are useful to answer the research questions described in section 2.1, specific selection criteria are defined.

This set of criteria supports the identification of scientific articles with similar quality and homogeneity (Villanueva and Wenzel 2007). This eases the evaluation and utilization of compiled data from those studies into the case study in Lima. The set of criteria is described below.

- **Functional unit related to plastic waste management techniques:** The main purpose of this systematic review is to obtain significant information from previous existing articles related to plastic waste management, to adjust it to the Peruvian context and perform a LCA study. LCA of waste management is a special and complicate topic, and only articles related to it will be useful for the study. This means that LCA of plastic production or waste management of other products (glass, organics), without including plastic waste are not being evaluated. This also applies to articles that are mainly related to construction or production waste management (e.g. waste from household appliances).
- **Comparison of different waste management techniques on plastic polymers other than PET:** Polyethylene terephthalate (PET) is one of the most

recycled plastic resins around the world. Mostly because this material is fully recyclable (by upcycling or downcycling routes). Several LCA studies related only to the evaluation of different techniques on PET recycling are available and are part of the references obtained during the WoS search. Since the focus of this study is the evaluation of MPW management options, it is important that the selected studies are not only related to one specific type of polymer and waste (e.g. PET bottles).

- **Availability of data:** One of the main objectives of pursuing a systematic review is the compilation of relevant and useful data for the development of an LCA of plastic waste for the Lima context. Thus, it is important that the references selected have available data, either within the text or in a separate document (supplementary information).

4.1.3 Evaluation criteria

Using LCA theory and the experience from previous systematic reviews in LCA studies (Villanueva and Wenzel 2007; Zumsteg et al. 2012; Zamagni et al. 2012), evaluation criteria for the assessment of the references remained after the literature selection criteria are defined. The considered evaluation criteria are important in relation to the main research question and sub-questions proposed in section 2.1, and guide the review of the studies and information gathered from them.

The evaluation criteria include the description of the goal and scope of the study, multifunctionality and allocation methods, types of electricity replaced, material substitution ratio, types of plastic evaluated, impact categories included, data availability and main conclusions drawn.

4.2 Case study and scenario development

The second part of this study consists of the environmental evaluation of the current situation of MPW management in Lima, Peru, and its comparison to possible treatment alternatives. The current situation, or baseline, consists of the disposal of MPW in either landfills or (illegal) open dumps. The use of (illegal) open dumps is a consequence of the insufficient number of landfills for the generated amount of MSW Lima has only four (04) landfill sites that is not enough for the almost 6,000 tons of MSW generated every day (MINAM 2013a).

The situation required by Peruvian Law of Solid Waste N° 27314 (Congreso de la Republica 2000), consists on the disposal of all MSW collected, including MPW, on landfills. The Peruvian Law and its Bylaw (MINAM 2010a) specify that "the final disposal of waste in the field of municipal management is performed by the method of landfill", including all materials collected in each municipality.

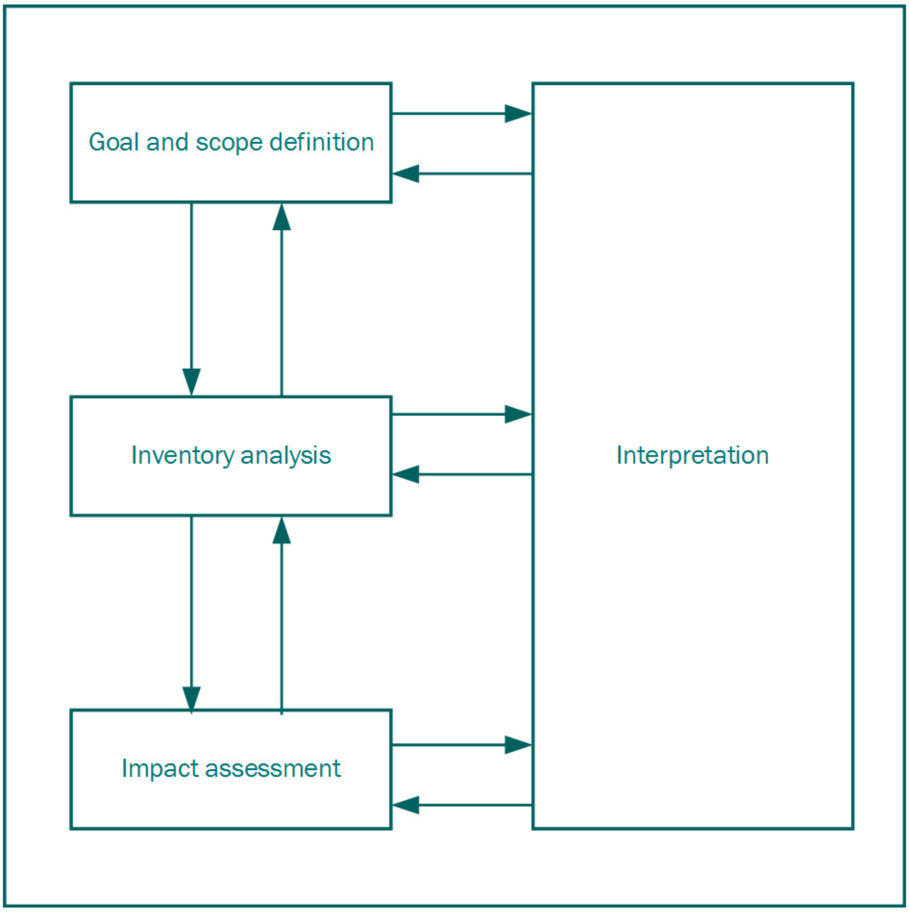
To develop an environmental evaluation of different alternatives for MPW management in Lima, different scenarios are going to be contemplated. These scenarios will include the current situation of MPW disposal in Lima, incineration of all MPW with energy recovery, and a combination of mechanical recycling and incineration of losses from recycling.

4.3 Method: Life Cycle Assessment

Life cycle assessment (LCA) is the ideal method for evaluating different alternatives of MSW management. An LCA is considered an integrated assessment analysing all relevant environmental impacts occurring from the beginning (cradle) until the end (grave) of a product's life. This tool gives a full picture while mapping impacts and potential problems shifting to other phases (Guinée and Heijungs 2005).

The LCA methodology is known world-wide and its structure has been agreed on a specified set of ISO standards known as ISO 14040-series. The defined framework follows four different, but all related, phases (see Figure 4-1): goal and scope definition, inventory analysis, impact assessment and interpretation (Guinée et al. 2002). The following sections describe the details of the LCA methodology.

Figure 4-1: Phases of a Life Cycle Assessment (Source: ISO 14040:2006)



4.3.1 Goal and scope

This is the first phase of a life cycle assessment and defines the working plan of the assessment that is developed. The goal includes the reasons for performing the study, the target audience and the intended application of the obtained results (Guinée et al. 2002).

The scope defines the system under study and the functional unit. The scope also includes the level of detail of the study and data requirements, the temporal, spatial and technological coverage, the processes coverage, assumptions and limitations (ISO 2006).

4.3.2 Inventory analysis

In this phase, the system boundaries of the products under study are defined, including the differentiation between economic and environmental goods. The flow diagrams with considered processes are included, as well as the collected data required for the analysis (Guinée et al. 2002). This phase also includes the approach of how multifunctional processes are going to be solved.

4.3.3 Impact assessment

In the third phase, the potential environmental impacts of the product system are evaluated. The results obtained during the previous phase of inventory analysis are processed and evaluated on their potential contribution to the selected impact categories. The covered impact categories and methods must be in line with the goal and scope of the study (EC-JRC 2010a).

4.3.4 Interpretation

In this phase, the evaluation of the results and assumptions is performed. Here, the findings of the inventory analysis phase and impact assessment phase are brought together with the goal and scope of the study. First, a consistency and completeness check is performed, evaluating that all data and relevant information is complete and consistent with the goal and scope. Then, a contribution analysis is performed, in order to identify significant issues or “hot-spots”. Finally, a sensitivity analysis of specific parameters is carried out, to improve the interpretation of results and evaluate how the results could be affected by different assumptions, allocation methods, among others (Guinée et al. 2002).

5. Systematic review results

5.1 Selected LCA studies

5.1.1 Bibliometric results

The bibliometric analysis is conducted using the WoS engine. For this, the keywords [Life Cycle Assessment], [plastic*], [waste] and [management] have been utilized in all databases for the period 2006-2016. This search resulted in 246 scientific articles.

The abstracts of the 246 resulted articles have been reviewed, to discard those that are not related to the topics LCA of MSW management and MPW management. Discarded articles include, for example, the study of the manufacture and distribution of plastics; LCA of a specific product (e.g. olive oil bottles); LCA of waste management of other products than plastics (e.g. batteries, aluminium cans); along with others.

After the abstract evaluation, 52 articles are kept and considered for further analysis with the defined literature selection criteria (see section 4.1.2). The list of articles is available in Appendix A.

5.1.2 Literature selection

Next, the selected articles are reviewed to discard studies with functional units not related to plastic waste management. The discarded articles are either a review of LCA of MSW; LCA of specific household appliances (e.g. television sets); construction wastes; or without specification on the type of waste treated. After this step, 26 abstracts remained for the next selection step.

Following that, another scanning is conducted, to discard articles that only considered one type of plastic polymer and/or one type of material (e.g. only PET bottles) reducing the amount of references to 13.

Finally, references without any data available either in the text or in additional supplementary information are also discarded, reducing the number to 10 selected references.

With these criteria, it is ensured that the selected articles can be used for compiling relevant and useful information, lessons learned and data for the case study, and that it includes the commonly available polymers in MPW (e.g. HDPE, LDPE, PS, PP, PET, PVC). In Table 5-1, the selected references related to LCA of plastic and municipal solid waste management are listed.

It is important to mention that the WoS only selects scientific articles as results, and this creates bias during the bibliometric evaluation, since reports or book chapters are not included. Also, during the evaluation of the selected articles, the report retrieved by Shonfield (2008) on "LCA of Management Options for Mixed Waste Plastics" in the UK is mentioned in two articles (Rigamonti et al. 2014; Sevigné-itoiz et al. 2015) as a reference for specific data for sorting techniques and source of information on LCA of plastic recovery techniques. This report has been added to the previously 10 selected articles, making a final total of 11 references.

Table 5-1: Resulting references from the bibliometric analysis and literature selection by using the Web of Science engine.

Autor (s)	Type	Location
Al-Salem et al. (2014)	MSW & PW	London, UK
Chen et al. (2011)	PW	Shenyang, China
Diaz and Warith (2006)	MSW	Toronto, Canada
Huysman et al (2015)	PW	Flanders, Belgium
Nishijima et al. (2012)	PW	Japan
Rigamonti et al. (2014)	PW	Western Europe
Sevigné-itoiz et al. (2015)	PW	Spain
Shonfield (2008) *	PW	UK
Tan and Khoo (2012)	MSW	Singapore
Tunesi et al. (2016)	MSW	Bologna, Italy
Yano et al. (2014)	PW	Japan

PW: Plastic Waste
MSW: Municipal Solid Waste
*Relevant report additionally included

5.2 Evaluation of selected LCA studies

The selected studies are assessed by evaluating and describing the fulfilment of the following criteria: goal and scope definition, system boundaries definition, multifunctionality definition, type of electricity replaced, material substitution ratio, types of plastic evaluated, impact categories, inventory data and main conclusions drawn.

5.2.1 Goal and scope

The selected references have a similar structure, comparing different ways of MSW and/or plastic waste management. Since all studies are issued from 2006 onwards, the goal of the reports was explicitly described on the studies. Most papers were developed to compare different scenarios of waste management techniques for MSW and/or plastic waste, from an environmental point of view. As identified also by Lazarevic et al. (2010) when evaluating different LCA studies, the selected references did not specify the purpose, application and the intended audience of the report in most cases.

In most papers the functional unit (FU) was correctly stated. Diaz and Warith (2006) did not include a specific functional unit, since their study described the development of a model for environmental waste management evaluation (WASTED model).

The defined FUs were similar, comparing different ways of management of a specific weight of waste (e.g. one ton per year or kilogram per year), or the generation of waste of a specific city per year (e.g. total waste generated in an area per year). Only one study, Tan and Khoo (2012), stated the FU of the study as “total waste generated in Singapore geographical area per year (2004)”, but they failed in mentioning the considered amount in numbers.

About the two types of modelling in LCA, attributional or consequential, there were mistakes observed when mentioning which modelling was developed. Attributional LCA (or ALCA) represents the potential environmental impacts that could be attributed to a product or a system during its life cycle. Attributional modelling uses average existing data or factual data and includes those processes that are considered to contribute to the impacts of the system under study as it is. Consequential LCA (or CLCA), on the other hand, identifies the possible consequences of a change due to a decision made in the foreground system on other systems and processes inside an economy. CLCA considers marginal processes, market mechanisms and are dynamic models (EC-JRC 2010b).

Only one study, Al-Salem et al. (2014), correctly specified the modelling as "Attributional LCA". On the other hand, two studies, Rigamonti et al. (2014) and Sevigné-itoiz et al. (2015) specified a "Consequential LCA" modelling, justifying it by the use of marginal electricity, and substitution for solving multi-functional processes, which is not enough to call an LCA study a consequential modelling. Consequential modelling also involves the use of marginal inventory data in general (not only marginal energy data), evaluation of the cause-effect using physical and market mechanisms, and the inclusion of all affected processes that could be affected by changes in the demand (Singh et al. 2013).

It is important to mention that the decision to use average or marginal processes is in fact connected to the type of modelling, attributional or consequential, of the system under study. An attributional modelling follows average processes, while a consequential modelling follows marginal processes (EC-JRC 2010b).

5.2.2 System boundaries

Almost all studies included similar unit processes: collection, transport, transfer, sorting or pre-treatment and final waste management (incineration, landfilling or recycling). In relation to the type of recycling processes, all studies included at least mechanical recycling, six articles included also chemical recycling and two articles, Tan and Khoo (2012) and Tunesi et al. (2016), did not mention a specific type of recycling in the text. In all studies, the incineration process included energy recovery.

Flowcharts representing the system boundaries of the studies were presented in eight references. From these, only two, Chen et al. (2011) and Yano et al. (2014), included a legend explaining the flowchart items. None of the flowcharts presented a differentiation between foreground and background processes, with the exception of

Al-Salem et al. (2014). Also, none of the flowcharts showed products leaving the system (e.g. recycled products, produced electricity or heat), with the exception of Tan and Khoo (2012). Three references, Huysman et al. (2015); Rigamonti et al. (2014); and Tunesi et al. (2016) did not include a flowchart in the study.

All of the references, with the exception of Huysman et al. (2015), included a description of the system boundaries on the text. However, the authors did not state a differentiation between the product system and the environment system. When evaluating waste management through LCA, the disposal of waste is considered as an economic process and not an emission to the environment. Therefore, these differentiations should be explicit pointed out in the text.

Also, three authors, Al-Salem et al. (2014); Rigamonti et al. (2014); and Tan and Khoo (2012), did not mention any cut-offs or irrelevant processes not included in the analysis. Only Shonfield (2008) and Diaz and Warith (2006) specified the exclusion of infrastructure on the analysis, even though any of the references included it.

5.2.3 Multifunctionality

In the selected studies, scenarios were developed to compare different alternatives and techniques for waste management. In all techniques (recycling, incineration and landfilling) by-products were generated (e.g. recycled pellets, electricity, heat, gas, etc.). A unit process that generates more than one product or achieves more than one function is defined as a “multifunctional process”. These “multifunctional processes” need to be solved by more defined data collection, system expansion, substitution or allocation methods (Guinée et al. 2002).

Only two studies, Al-Salem et al. (2014) and Rigamonti et al. (2014) included a description of multifunctional processes and the selected method to solve it. Rigamonti et al. (2014) correctly specified the use of substitution for solving a multifunctional problem, but did not included it in the flow diagram of the system boundaries. Al-Salem et al. (2014) mentioned the use of system expansion method but ended up applying the substitution method instead.

Sevigné-itoiz et al. (2015) and Shonfield (2008) included a vague and not correct definition of multifunctionality and specified solving the problem with system expansion. Both studies used the substitution method instead. Both studies also included the substituted processes in their flow diagrams.

The remaining studies did not provide a definition of multifunctionality, nor a method for solving these problems. However, they still mentioned that the system under study considered the impacts avoided by recycling or incineration, and that the avoided burden was subtracted from the processes total impacts. This indirectly informs the reader that they solved the multifunctionality problem by the substitution method, even though it was not stated explicitly in the text.

5.2.3.1 *Type of electricity replaced*

Recycling and incineration with electricity recovery of plastic waste produce by-products that can be used as a replacement of virgin material and conventional electricity. In the selected studies, almost half of them assumed that the electricity generated was used as a replacement of marginal electricity production, related to electricity from coal, natural gas or fossil fuels. The other half assumed that the electricity generated was used as a replacement of the average electricity mix of the area, that varies geographically.

As mentioned by Shonfield (2008), both options of energy source should be evaluated by a sensitivity analysis. A sensitivity analysis makes the results of the study more robust for decision making in the future (Lazarevic et al. 2010).

5.2.3.2 *Material substitution ratio*

The material substitution ratio is the proportion of virgin material (virgin plastics or other materials) that could be replaced by the recycled material. This concept is important, as it affects directly the amount of environmental impacts that could be avoided by transforming waste into products.

In the selected studies, different replacement ratios were observed among the studies (see Table 5-2). Sevigné-itoiz et al. (2015); and Shonfield (2008) used a replacement ratio of 1:1, assuming that all recycled material can replace virgin material directly. Chen et al. (2011) and Tunesi et al. (2016), used a more conservative replacement ratio of 1:0.8. Nishijama et al. (2012) and Rigamonti et al. (2014) used different replacement ratios for different polymer groups, within the range of 1:0.6 and 1:0.9.

Sevigné-itoiz et al. (2015) and Shonfield (2008) evaluated the sensitivity of this assumption by replacing the ratio 1:1 with 1:0.5 and 1:0.2, respectively. The sensitivity analysis showed that the influence of the replacement ratio is high in all the impact categories evaluated. It could even change the preferred management option when comparing mechanical recycling with incineration.

The effects of the assumed substitution ratio were affected by the assumptions made in each specific study. But, in general, it is observed that the environmental performance of recycling schemes is directly affected by the quality of the recycled sub-product obtained. Thus, the quality of the possible recycled material should be part of the final decision of the disposal alternative (Shonfield 2008).

Table 5-2: Different replacement ratios included in the reviewed references

Author (s)	Type of resin	Replacement ratio
Huysman et al. (2015)	General	1:1
Nishijama et al. (2012)	PE-PP combination	1:0.5
	PS-PET combination	1:0.75
	Single resins	1:0.6
Rigamonti et al. (2014)	PET	1:0.755 - 1:0.81
	HDPE	1:0.9 - 1:0.81
	Polyolefins	1:0.6
Tunesi et al. (2016)	General	1:0.81
Sevigné-itoiz et al. (2015)	General	1:1
Shonfield (2008)	General	1:1
Yano et al. (2014)	General	1:0.5

5.2.1 Types of plastic evaluated

The studies reflected that the composition of municipal waste plastics varies notably per geographical area. As mentioned by Shonfield (2008), the composition of plastic mix has a high variation, even from batch to batch that enters the separation system. The different compositions of plastics on the selected studies are showed in Table 5-3. Some studies, Huysman et al. (2015); Sevigné-itoiz et al. (2015); Tan and Khoo (2012); Tunesi et al. (2016); and Yano et al. (2014), considered the plastic mix as a whole without specifying the different percentages of polymers contained.

Table 5-3 shows great differences among the polymer concentrations in the different references. This is mainly because of the definition of plastic waste considered in the different studies, and other specific local characteristics. Nishijama et al. (2012), for example, did not include all MPW in the study, and only considered household containers and packaging plastics. Rigamonti et al. (2014), similarly, included in the assessment only HDPE, LDPE and PET, and the rest was considered as a nonrecyclable fraction. Shonfield (2008) evaluated the plastic waste in UK after being processed in a material recycling facility (MRF), where all materials that could be easily recycled or have a high value were removed. Finally, Al-Salem et al. (2014) and Diaz and Warith (2006) did not define if the plastic waste sample corresponded to MPW, a part of it, or to all plastic waste collected in UK or Toronto, respectively.

Al-Salem et al. (2014) and Chen et al. (2011) excluded the evaluation of PET plastic, while Huysman et al. (2015) and Nishijama et al. (2012) excluded the evaluation of bottles made from PET plastic. This is because PET plastic, especially PET bottles, are normally collected and recycled separately from other plastic wastes. In Shenyang, China, for example, all PET plastic is collected and transported to other provinces to be recycled (Chen et al. 2011).

Table 5-3: Polymer composition of plastic waste in the reviewed references

Author (s)	HDPE %	LDPE %	PP %	PS %	PVC %	PET %	Others %
Al-Salem et al. (2014)	13.2	24.3	18.5	6.3	18.8	-	18.9
Chen et al. (2011)	20		20	5	20	0	35
Diaz and Warith (2006)	7	33	2	9	1	14	34
Nishijama et al. (2012)	11.8	7.7	17.5	18.2	4.2	6.5	34.2
Rigamonti et al. (2014)	13	39	-	-	-	25	23
Shonfield (2008)	15		40	6	11	17	11

5.2.2 Impact categories

ISO 14044 (2006) mentions that the life cycle impact assessment must include a "selection of impact categories, category indicators and characterization factors". The impact assessment in the selected studies was explicitly described in 9 of 10 references, including in most cases a reason for the selected impact categories. The selected impact categories in each reference is shown in Table 5-4. Only Nishijama et al. (2012) did not define nor explain the selection of the impact categories in the text, which were call "CO_2 emissions" and "fossil resource consumption" in the graphs.

Five studies mentioned characterization factors (e.g. GWP, AP, EP) instead of impact categories (e.g. climate change, acidification, eutrophication). Only three studies, Rigamonti et al. (2014); Tan and Khoo (2012); and Yano et al. (2014) correctly mentioned the impact category names. The impact category of climate change, using the global warming potential as characterization factor with a time horizon of 100 years, was included in almost all studies.

In five studies, the impact categories acidification, photochemical oxidation, eutrophication and (human and ecological) toxicity were also included. Other categories included were fossil fuel savings, fossil resource consumption and resource use, which refer to the category impact called "abiotic depletion". The effects of different methodology selection are not part of the scope of this study.

The impact assessment methods used are only clearly specified in half of the selected studies. The used methods were CML[1] (Al-Salem et al. 2014; Shonfield 2008); Cumulative Exergy Extraction from the Natural Environment (CEENE) (Huysman et al. 2015); IPCC 2007 (Sevigné-itoiz et al. 2015) and EDIP[1] method (Rigamonti et al. 2014). In the other case studies the methods were not specified.

Also, as specified by ISO 14044 (2006), for comparative LCA studies that are intendent to be disclosed to the public, a set of category indicators need to be selected that are sufficiently comprehensive. In the case of the selected case studies, most studies included between one and four impact categories, excluding other impact category indicators that could be also significant in the case of evaluating MSW management.

[1] Although often indicated as such, CML and EDIP are not methods but family of methods.

Table 5-4: Impact categories included in the reviewed references

Impact categories	Al-Salem et al. (2014)	Chen et al. (2011)	Huysman et al (2015)	Nishijima et al. (2012)	Rigamonti et al. (2014)	Sevigné-itoiz et al. (2015)	Shonfield (2008)	Tan and Khoo (2012)	Tunesi et al. (2016)	Yano et al. (2014)
Climate change								X		
(incorrectly called)										
Global warming [potential]	X	X			X	X	X		X	X
CO2 emissions				X						
Acidification	X				X		X	X	X	
Photochemical oxidation	X				X		X			
Eutrophication	X				X		X			
Ozone depletion							X			
Abiotic depletion							X		X	
(incorrectly called)										
Resource use								X		
Fossil fuels savings		X								
Fossil resource consumption				X						
Ecotoxicity					X			X		
Human toxicity					X		X			
CEENE			X							

5.2.3 Inventory data

The systematic review is developed also to obtain useful and relevant data from existing studies related to MSW and MPW techniques for applying an LCA of MPW management in Lima, Peru. After the analysis of the available data, an adaptation of relevant parameters to the Peruvian reality is performed when required.

As mentioned by Price and Kendall (2012), many of the available LCA studies are not transparent enough in their reporting and that does not facilitate a systematic review altogether. A description of the main problems encountered during the review of the studies are detailed below.

Al-Salem et al. (2014) included detailed data only for some processes, related to chemical recycling. For other processes, i.e. mechanical recycling, the data available was summarized as characterization results. The unit process data was not complete. Since data summarized as characterization results cannot be used as unit process data, this study is not used to obtain information for the case study.

Huysman et al. (2015) included supplementary information. However, the data available was listed in tables per recycling alternative, without stating clearly the differences between inputs and outputs. Also, the names of the processes in the tables did not match the unit processes' names in the text. This lack of clarity during reporting, invalidates the available data, which cannot be used in the case study. Some data was included in the main text, but was not specific for unit processes.

Rigamonti et al. (2014) included data related only to energy consumption of machinery, but did not include the inputs and outputs of unit processes of the system under study. Also, for two scenarios, the values of total energy used and transport distances used were described as totals for the processes but without an explanation of how the numbers were obtained.

Sevigné-itoiz et al. (2015) developed a study in two parts, first a material flow analysis (MFA) of the plastic waste in Spain, and second, an LCA of the plastic waste management alternatives. The available supplementary information contained specific data only for the MFA. However, for the LCA, the data included only described the transport distances considered. In the main text, only the sources of the data used for the unit processes were available, but the inputs and outputs were not included.

Tan and Khoo (2012) based their study on total waste generated in Singapore in the year 2004, but they did not provide the numerical value of that total waste generated amount. Also, they did not provide the percentages of each waste fraction (e.g. food waste, plastic waste, paper waste, etc.). The data provided in the text was in function of the different waste fractions generated. Thus, without the amounts of total waste generated in Singapore and the waste fraction amounts, it was impossible to understand and extract the data available.

Tunesi et al. (2016) did not include inventory data of the unit processes studied. The data available in the text was related to the results per impact category. Data summarized as characterization results cannot be used as unit process data.

Chen et al. (2011) included inventory data in the text, differentiating inputs from outputs. The source of the data was included; however, the original data is only available in Japanese. Chen et al. (2011) modified and adjusted the data to fit the composition of Shenyang's MPW, but the original data and calculations for the adjustment were not available. This makes it impossible to use these data and learn from its adaptation.

Yano et al. (2014), similarly to Chen et al. (2011), used data from Japanese sources, which makes it impossible to corroborate the data included in the text, because of language issues. Yano et al. (2014) included an extended compilation of input-output data for the most important processes involved. However, there was a lack of explanation of some terms considered in the data which makes it hard to follow. For example, the mechanical recycling data was based on "tonnes of bales", but the description of the amount of plastic in one ton of bales is missing.

Nishijama et al. (2012), included in the text a table with the data of the most important unit processes. This study also included a waste description of the exact composition of the plastic waste per fraction, and based the unit processes data in that composition. Also, the description of the mechanical recycling process was available and well described, including types of plastic considered and processed. From this study, the data for collection, compaction and mechanical recycling processes is going to be selected and adapted, when needed, to the Peruvian case study.

Shonfield (2008) studied different disposal options for domestic plastic waste, including technologies for sorting and separation. The study included an appendix with all the primary data used in the assessment of sorting technologies, with comments and assumptions. The source of data used for landfilling and incineration was mainly Ecoinvent v1.3, and was also included. From this study, the sorting process data is going to be selected and adapted to the Peruvian case study.

Diaz and Warith (2006), worked on the elaboration of a model to evaluate waste management alternatives. The study included the raw data used as base for the model, for different alternatives and stages of waste treatment. One of the stages was the transfer stations for collected waste. This information is going to be selected and adapted to the Peruvian case study.

The selected data mentioned in Table 5-5, taken from Nishijama et al. (2012), Shonfield (2008) and Diaz and Warith (2006) is used to model the processes of: collection, compaction, transfer, mechanical sorting and mechanical recycling. The processes of transport, incineration and landfilling, and data gaps and complementary background data is completed with Ecoinvent database v2.2 (2010). The selection of data is based on the availability of unit process data in the studies and transparency during reporting of used data. Since the selected data comes from studies performed in developed countries, it is possible that it is not completely representative of the Peruvian situation. Selected data and complementary data for the case study is available in Appendix B.

Table 5-5: Selected processes for the case study, technologies and sources of data

Process	Technology / facility	Source	Location
Collection	Curbside collection	Nishijama et al. (2012)	Japan
Compaction	Compacting truck	Nishijama et al. (2012)	Japan
Transport	Diesel trucks	Ecoinvent (2010)	Switzerland
Transfer	Transfer station	Diaz and Warith (2005)	Toronto, Canada
Mechanical sorting	NIR technology	Shonfield (2008)	UK
Mechanical recycling	Mechanical recycling facility	Nishijama et al. (2012)	Japan
Incineration	CHP plant	Ecoinvent (2010)	Switzerland
Landfilling	Sanitary landfill / open dump	Ecoinvent (2010)	Switzerland

5.2.1 Main conclusions

The selected studies evaluated different techniques of waste management, i.e. landfilling, incineration, mechanical recycling and chemical recycling. They all concluded that mechanical recycling, in combination or not with other techniques, was the most favourable alternative for reducing GHG emissions. Chen et al. (2011), Huysman et al. (2015) and Sevigné-itoiz et al. (2015) concluded that mechanical recycling reduces more GHG and resource consumption than incineration and landfilling. Al-Salem et al. (2014), Tan and Khoo (2012) and Tunesi et al. (2016) mentioned that a combination of mechanical recycling and incineration was a better alternative than landfilling. Finally, Nishijama et al. (2012), Rigamonti et al. (2014) and Shonfield (2008) mentioned that mechanical recycling combined with chemical recycling for the non-recyclable fraction showed better environmental performance than incineration and landfilling. Nevertheless, Rigamonti et al. (2014) and Shonfield (2008), studies that included seven impact categories, concluded that no scenario evaluated arose as the best option for all the impact categories.

Al-Salem et al. (2014), Chen et al. (2011), Sevigné-itoiz et al. (2015) and Tunesi et al. (2016), concluded that the results were highly influenced by the substitution ratio with recycled materials and the avoided emissions from the substituted material (e.g. virgin plastics, electricity). Al-Salem et al. (2014), Nishijama et al. (2012) and Yano et al. (2014) mentioned that a higher quality recycled material, with a higher substitution ratio, is affected by the collection and separation efficiency, and the reprocessing techniques chosen.

Al-Salem et al. (2014), Chen et al. (2011), and Huysman et al. (2015) mentioned that a high substitution ratio also depends on the capacity of the local markets to absorb the recycled materials. They mentioned that there is a need for more incentives and subsidies from the governments to promote and increase the acceptance of recycled materials.

The majority of references included a contribution analysis of the different phases in their systems. All of them concluded that the transport and collection phases had a minimum contribution to the overall impact of the alternatives. Also, the biggest reductions of environmental impacts were related to the avoidance of emissions of substituted products. Two references, Al-Salem et al. (2014) and Tan and Khoo (2012), mentioned that the transport stage was more relevant for the acidification impact category.

The vast majority of the studies also performed a sensitivity analysis, to evaluate the effect in the results some of the main assumptions taken during the studies. Al-Salem et al. (2014); Chen et al. (2011); Nishijima et al. (2012); and Shonfield (2008) evaluated the effect of variations on the substitution factor. They concluded that a reduction on the substitution factor directly increased the impacts on the climate change category, because of the reduction in avoided emissions for substitution. Al-Salem et al. (2014) and Shonfield (2008) also mentioned that low substitution ratios (below 50% and 70%, respectively) would make chemical recycling more environmentally preferable to mechanical recycling.

Also, the effect of choosing marginal electricity as the source of electricity that could be replaced was evaluated in two studies, Rigamonti et al. (2014) and Sevigné-itoiz et al. (2015). They concluded that when marginal electricity was chosen, more savings were observed, because of the substitution of electricity produced from coal or fossil fuels.

5.3 Systematic review conclusions

From the evaluation, it can be concluded that it is highly important to be precise during the description of the study especially in the first and second phase, of goal and scope definition and inventory analysis. For example, the lack of precision during the definition of the FU as observed in Tan and Khoo (2012), who did not mention an amount in numbers, makes the study irreproducible, difficult to interpret and to compare to other similar studies. Also, the assumptions and cut-off processes need to be correctly described, to have more confidence in the main results, which was not the case for most of the studies.

Also, it is possible to conclude that there is still some confusion among the authors related to concept definitions on LCA studies. This is mainly observed during the description of multifunctionality and impact categories, where most of the time concepts were mixed or incorrectly described.

The results related to the effects of the substitution ratio for virgin materials emphasise the importance of obtaining a recycled plastic of high quality. This is affected by the first steps of the process, during the collection, transport and sorting of the materials to be recycled. A more conservative replacement ratio, could obtain more realistic results. Three studies used a ratio of 1:0.8, meaning that there will be a 20% of loss in quality in the recycled plastics.

The data availability and transparency was also an issue observed in the studies. Most studies only included part of the data used for some economic processes. Most of the selected studies were not reproducible, mainly because of lack of complete information and clear description of how data was obtained. Still, data for some unit processes in the case study could be obtained from three studies that were considered to be the clearest ones, even so no completely transparent (Diaz and Warith (2005), Nishijama et al. 2012 and Shonfield 2008).

Almost all studies are placed in a developed country. Only Chen et al. (2011) evaluated waste management options in a developing country, China. They mentioned that it was hard to find accurate data for China, especially related to waste composition and fractions. They used data from Japan and applied it to the China context, by mainly modifying the composition of the waste and the type of electricity available in China.

The main alternatives evaluated for waste management in the studies were landfill, incineration and mechanical recycling. Some studies also included a combination of mechanical recycling and incineration, to avoid as much as possible the disposal of plastics in landfills.

6. LCA case study: MPW management in Lima, Peru

6.1 Scenarios

Most of the selected studies included three to five scenarios of waste management techniques. Nishijima et al. (2012) and Shonfield (2008) worked with 27 and 16 different scenarios, respectively. In these two cases, the scenarios were a combination of different technologies available in the market for material and chemical recycling. Following the scenarios described in these studies, specific scenarios for this case study are developed.

This case study explores and compares the current situation of MPW management (landfilling and open dump) with a combination of incineration and mechanical recycling options. The plastic mix considered in the case study includes flexible and rigid plastic packaging and containers of polymer types and colours typically available in the MSW in Lima.

- **Scenario SC1.** This scenario is the baseline scenario. Here, the current situation in Lima is studied, which includes the generation of 290 kt of MPW per year, from which around 75% are landfilling and the rest are disposed in (illegal) open dumps and water bodies (MINAM 2013a). It is difficult to evaluate the environmental consequences of plastic waste in open dumps and water bodies. It is assumed that the waste produces a leachate that goes directly to the soil and water bodies, as well as GHG released to the environment. In this scenario, as a base line scenario, 75% of all MPW is disposed in sanitary landfills and 25% is disposed in open dumps. Also, it is important to mention that gas emissions in landfills in Lima are almost not collected, and are instead released to the environment.
- **Scenario SC2.** To explore if incineration of all plastic waste is a better option, compared to the baseline scenario, this second scenario is created. It includes the incineration of all MPW in a municipal incineration plant. The electricity generated is assumed to be inserted as part of the electricity mix in Lima, which is assumed to be 50% hydropower and 50% thermoelectric from natural gas

(SNMPE 2016). The obtained ash from the combustion process is assumed to be landfilled.

- **Scenario SC3.** In this scenario, the option of mechanical recycling of MPW is explored. Here, the main MPW fractions PET, PE, PP, PS and PVC, are manually separated, sorted and mechanically recycled. It is assumed that first, MPW is separated in two types, hard plastics and plastic bags. Then, the hard plastics are sorted by polymer through NIR technology. Material loss and unsorted plastics are derived to incineration, following the same assumptions in **SC2**. The material substitution ratio is assumed to be 1:1, which means that from 1 kg of recycled plastics, 1 kg of virgin plastics could be replaced.

  The amount of MPW that goes to mechanical recycling is assumed to be 95% of the total plastic waste collected. The rest, 5%, is assumed to be unsorted plastics, which are derived to an incineration plant. From the 95% of MPW that goes through recycling, 10% is assumed to be plastic losses, which are also derived to an incineration plant. To sum up, from the total MPW collected, 85.5% is mechanically recycled to recycled plastic pellets, and 14.5% is incinerated producing electric energy.

6.2 Goal and scope

The first phase of an LCA study is the definition of the goal and scope. Here, the objectives and aim of the research are defined, followed by the establishment of the functional unit and alternatives.

6.2.1 Goal of the study

Lima, the capital and biggest city of Peru, has been growing fast economically and demographically since the last decade, provoking an accelerated growth in the generation of MSW. Municipalities are currently incapable of dealing with this MSW generation growth, mainly because of the lack of infrastructure to allow safe waste disposal in the cities. Lima generates around 40% of the MSW of Peru. From this, it is estimated that around 75% is disposed in sanitary landfills and the rest, 25%, is disposed in open dumps and water bodies, without leachate treatment or gas collection system. Also, sanitary landfills do not include gas collection systems, and most gases generated are directly emitted to the atmosphere.

From the total MSW generated in Lima, 10% or 290 kilotons are plastic waste. Plastics disposed in open dumps and landfills will remain non-degraded for hundreds to thousands of years (Barnes et al. 2009), and become a hazard for human health and the environment. Thus, the city of Lima needs to improve the way they are dealing with MSW and, especially, with MPW.

The system under study is the MPW management in Lima, Peru. The goal of this part of the study is to compare and identify which MPW management alternative has a better environmental performance. For this, a comparative LCA between three different scenarios of waste management is developed. The analysis includes the processes of collection, compaction, transport, transfer, sorting and cleaning, recycling, incineration and landfilling.

The target audience of this report is the Peruvian decision makers and environmental authorities in charge of promoting a better management of the produced solid waste in the country. The study is developed under the supervision of the expert reviewers Dr. ir. J.B. Guinée and Dr. ir. G. Korevaar.

The free software CMLCA v5.2, developed by the Institute of Environmental Sciences (CML) from Leiden University is used to perform the LCA study. The framework detailed in ISO 14040 is followed and the CML-2001 mid-point family of methods is used for the impact assessment.

6.2.2 Scope definition

The LCA study is limited to the case of Lima, Peru. The information available related to MPW generated in Lima, current management alternatives, type of electricity used in Lima and type of plastics, is collected and used.

The study includes the collection, compaction, transport, transfer, sorting, mechanical recycling, incineration and landfill stages. The study does not include the impacts of generation of MPW and separation of MPW from MSW, which is assumed to be done manually at the recycling facility. Manual separation, as mentioned by Chen et al. (2012) and Rigamonti et al. (2014), allows a higher separation and purity of the processed waste.

The study uses an attributional approach, using average data and solving the multifunctional problem by partitioning. Also, the study considers the more important physical flows in the selected processes. The level of detail of the study is enough to bring important conclusions about better practices on plastic waste management in Lima, Peru.

For this study, the evaluation only includes environmental impacts. Nevertheless, waste management include other impacts not related to the environment, for example economic impacts, related to new infrastructure, or occupational health impacts on waste collectors (Laurent et al. 2014b). These impacts are not addressed in the present study.

6.2.2.1 *Functional unit*

The functional unit represents a determined quantity of waste generated and managed in different ways in a delimited area. In this study, the functional unit is "managing 1000 kg of generated MPW in Lima, Peru". The alternatives are represented by scenarios and include a combination of open dump disposal and landfilling of MPW, as a baseline scenario, incineration of all MPW and a combination of mechanical recycling and incineration of MPW.

6.3 Inventory analysis

This chapter describes the procedure for collecting and adapting data to the Peruvian case study. Differences between the type of data used (primary data, data retrieved from literature review and databases) are explained, including all the assumptions made in this study. The database used in this study for the background processes is Ecoinvent v2.2 (2010).

The emission factors come mainly from Ecoinvent (2010), with the exception of the emissions of the disposal of plastic waste in open dumps and sanitary landfills, where the emissions have been calculated using the available datafiles “13_MSWIv2.xls” and “13_MSWLFv2.xls” from Ecoinvent (2010) and Doka (2008). The modelling of open dumps and sanitary landfills for the Peruvian context are described in Section 6.3.2.

The results of the inventory analysis are presented in Appendix C as a table listing all the inputs and outputs to/from the environment quantified and associated with the determined functional unit.

6.3.1 System boundaries

The system boundaries comprise the collection, compaction, transfer, transport, treatment and final disposal of MPW. The items considered are all plastic containers and plastic packaging waste generated in Lima. The plastic types found in Peruvian plastic mix are mainly polyethylene terephthalate (PET) bottles, hard plastics and plastic bags. Hard plastics are assumed to be a combination of polypropylene (PP), polyethylene (PE), high density polyethylene (HDPE) and (PVC), and it is also assumed that the amount of hard plastic is divided equally in these four fractions. Plastic bags are assumed to be low density polyethylene (LDPE).

When plastics are dumped on landfills, after a hundred years only a small part of the potentially harmful substances contained are released. This means that landfills delay the release of the emissions of today’s waste to the future (Doka 2009). In order to include all potential emissions from landfills, long time horizons are included in the landfill process. This means that all emissions are inventoried and treated as short-term emissions, regardless of when they are released.

This study includes the modelling of open dumps in Lima. To achieve this, the report of Doka (2009) on “Life Cycle Inventories of Waste Treatment Services” and Excel calculation workbooks “13_MSWIv2.xls” and “13_MSWLF2.xls” are used. For open dumps, it is assumed that all leachate is infiltrated to the underground water, and all landfill gases are released directly to the environment. The leachate volume and characteristics, and landfill gas characteristics are obtained from the Excel calculation workbooks mentioned in this paragraph and are shown in Appendix B.

Waste management requires specific infrastructure and equipment, being different for each management alternative (landfill, incineration, recycling). The infrastructure needed for landfilling (i.e. sanitary landfill facility) and incineration (i.e. municipal waste incineration plant) are included in the selected Ecoinvent processes. For the case of the recycling facility, there is no information related to plastic recycling plants in Ecoinvent or in the studies evaluated during the systematic review. In order to represent an area where the recycling operations take place, an approximation using the unit process "waste paper sorting plant" is included, assuming that the facilities of both processes would be similar enough.

The flowcharts representing scenarios SC1, SC2 and SC3 are presented below in Figures 6-1, 6-2 and 6-3. The flow diagrams include the unit processes, economic inputs and outputs of each process, and the connections between them. In these diagrams, environmental inputs and outputs are not included. The first stages of collection, compaction and transport are similar in the three scenarios. Also, scenarios SC1 and SC2 include a transfer process, which is assumed to not be necessary in SC3. This is because, it is assumed that MSW would be transported directly to the recycling facility for manual separation and mechanical recycling.

Figure 6-1: Flow diagram of SC1 (baseline scenario)

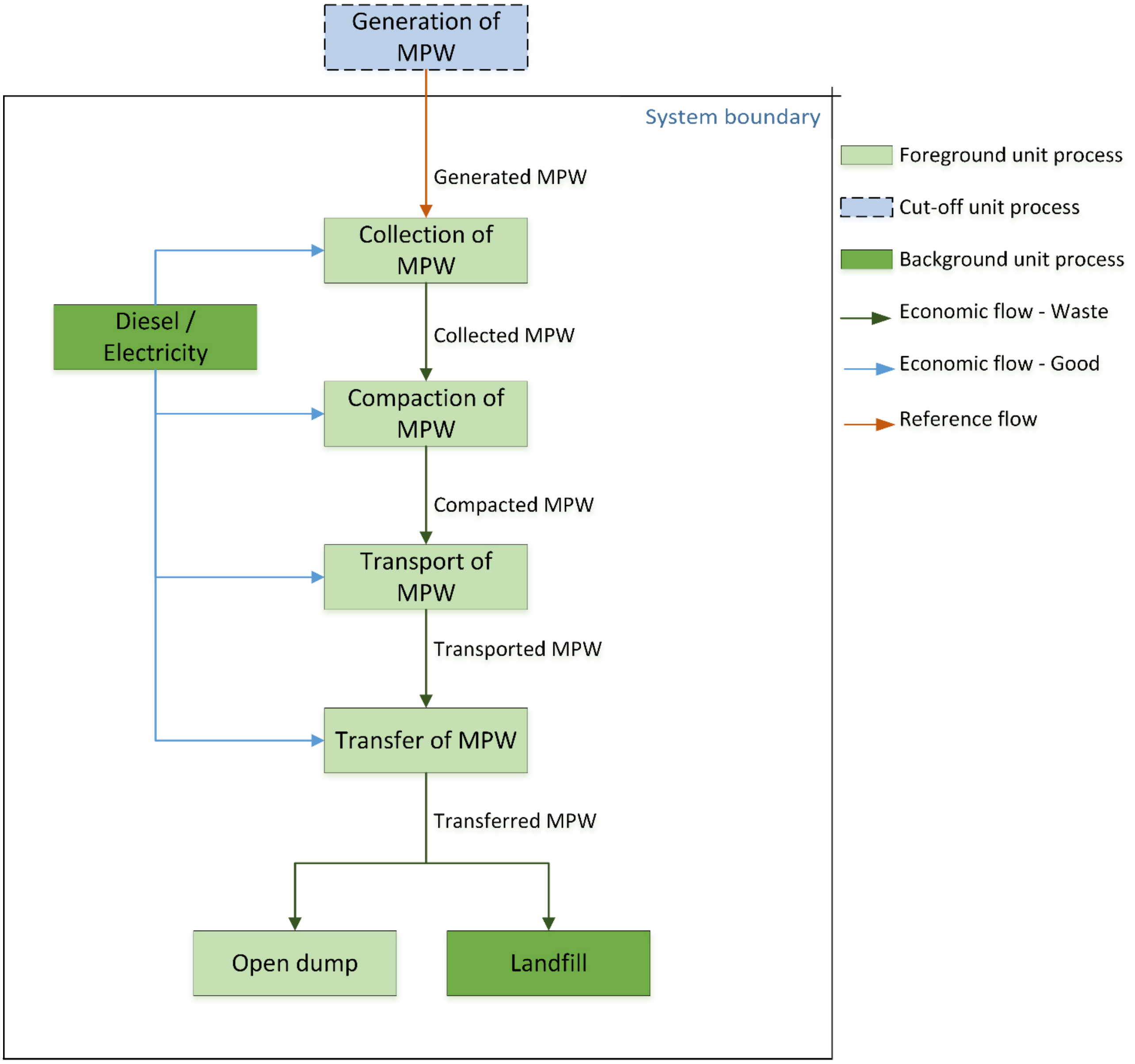


Figure 6-2: Flow diagram of SC2 (incineration scenario)

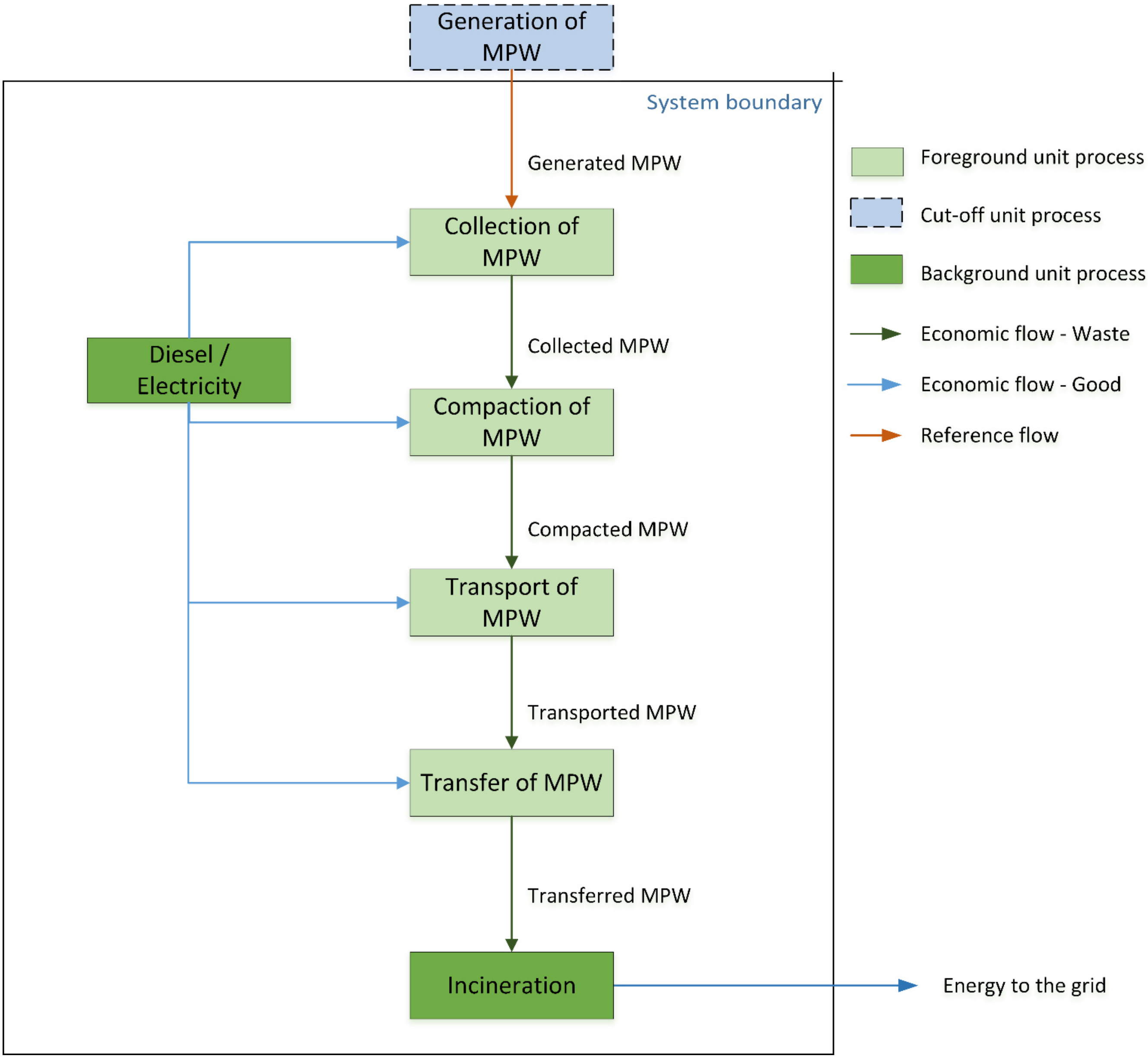
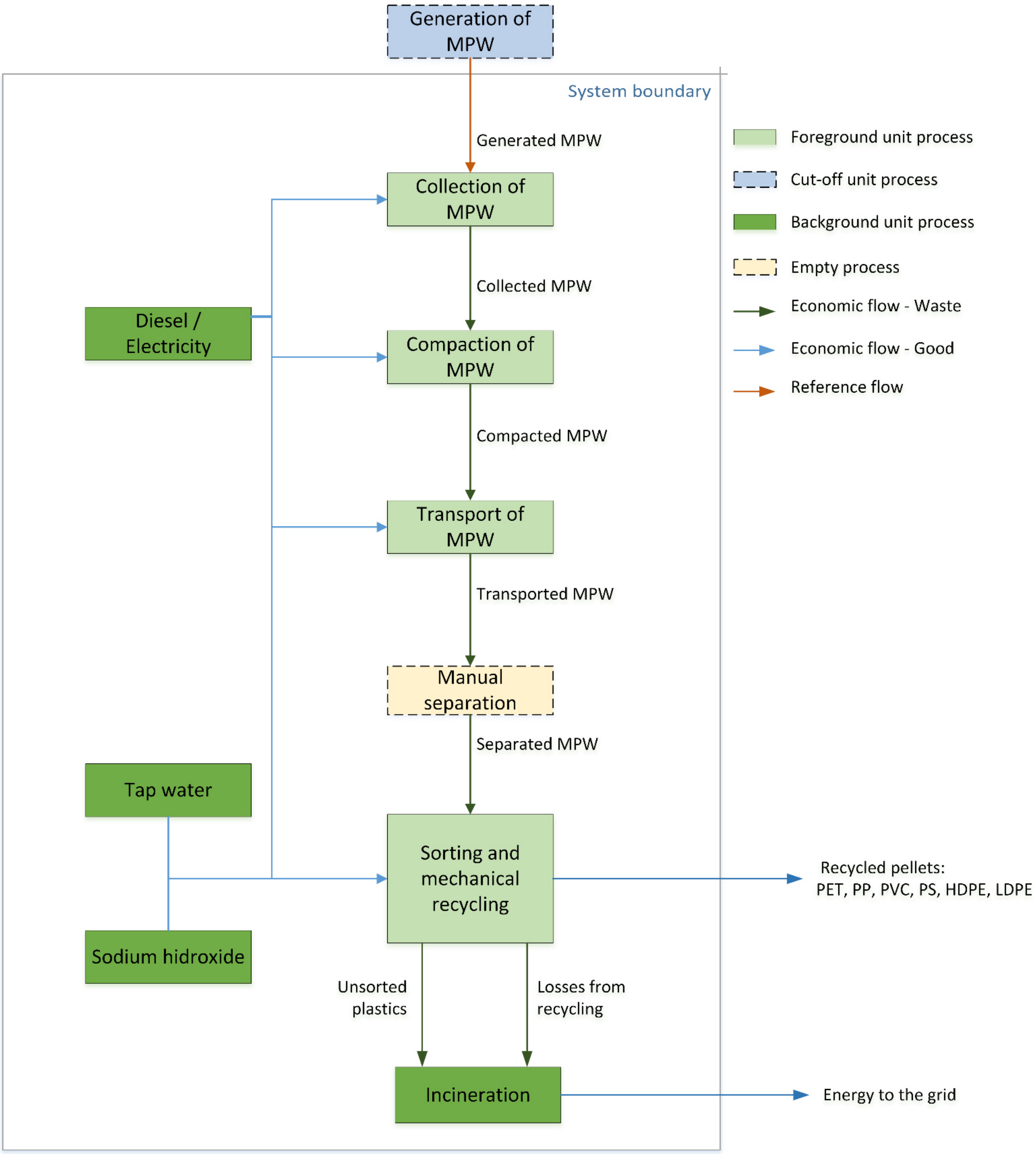


Figure 6-3: Flow diagram of SC3 (mechanical recycling scenario)



6.3.1.1 *Cut-off processes*

The study does not include the impacts of generation of MPW. Also, the separation of MPW from MSW, which is assumed to be done manually at the recycling facility, is not included in the report. The manual separation assures a higher separation rate and purity, before and after the sorting facility.

In the second scenario, SC2, and third scenario, SC3, it is assumed that the incineration of MPW and losses from sorting and recycling produce electricity. This electricity will enter the Peruvian electricity mix. Additional electrical connections and infrastructure for this assumption are not considered in the evaluation.

SC3 produces recycled pellets, that are assumed to be sold as replacement of virgin plastic pellets. The transportation, posterior use and disposal of the recycled pellets in the manufacturing plants are not included in the assessment. This is because these processes are beyond the point of allocation and belong to a different system.

6.3.2 Data collection

The data for the processes of collection, compaction, transfer, mechanical sorting and mechanical recycling are taken from Nishijama et al. (2012), Shonfield (2008) and Diaz and Warith (2006), as described in Table 5-5 and detailed in Appendix B. Data for the processes of transport, incineration and landfill, data gaps and complementary background data is completed with Ecoinvent database v2.2 (2010).

For the processes of collection and compaction, Nishijama et al. (2012) included only the amount of diesel (in litres) used for the collection lorries during both stages. If only diesel is considered in those processes, the impacts of the use of the diesel (burnt by the lorries) and the emissions related to this are not considered. For a more realistic impact evaluation, the distance travelled by the collection trucks need to be estimated. The Ecoinvent process "transport, municipal waste collection, lorry 21t[CH]" estimates that each kilometre of transport one ton of waste consumes 0.336 kg of diesel. Using this relation, it is estimated that the collection stage travels 84.8 km per ton of waste (tkm), and the compaction stage travels 19.4 km per ton of waste (tkm).

Transport in all scenarios is assumed to be carried out by a 21 tonnes lorry, and is modelled with the Ecoinvent process “transport, municipal waste collection, lorry 21t[CH]”. Also, it is assumed that lorries transport a full load and an empty load during return. Transport distances are assumed to be 50 km in total in all the alternatives. An accurate estimation of the actual distances is not part of the scope of this study and the assumed distances are only a guess of the possible distances of the transported wastes.

When necessary and possible, the collected data is adapted and modified according to the Peruvian context. Information about solid waste generation is available for 2014, per capita and per district, as part of the Peruvian environmental statistics (INEI 2015). Additional information, such as final destination of solid waste, is obtained from the report “Diagnosis of Solid Waste in Peru”, developed by the Environmental Ministry of Peru (MINAM 2013b).

Specific considerations and assumptions taken in the modelling of the three scenarios are described in detail in the following sections.

6.3.2.1 *Modelling sanitary landfill for the Peruvian context*

Lima counts four (04) sanitary landfills for the disposal of the MSW generated in the city. It is assumed that all of them are equipped with leachate collection pipes and leachate treatment units. Also, it is assumed that all of them have gas chimneys to realise the gases generated in the interior of the landfill into the atmosphere.

The collection of biogas from sanitary landfill and posterior incineration to produce electric energy is not well developed in Peru. There is only one sanitary landfill among the existing four that could implement a collection system for biogas with later incineration and insertion of the electricity into the national electricity grid. However, the collection of biogas occurs only for one part of the total biogas generated in the landfill and this percentage is unknown. Also, reports related to the performance of this gas collection system mentioned that the system was only able to collect less than 50% of the predicted amount at the beginning of the project (MINAM 2013a). Thus, since the percentage of the collected and incinerated biogas of this landfill is unknown, it is assumed for this case study, that all gases are emitted to the atmosphere without previous treatment.

To model sanitary landfill, the Ecoinvent process "disposal, plastics, mixture, 15.3% water, to sanitary landfill" is used as a base. In this process, the collection and treatment of leachate is included. Also, this process assumes that 53% of the generated gases in the landfill are directly emitted and 47% can be recovered and burned (Doka 2009a). In order to modify this process, and assume instead that 100% of the landfill gases are emitted to the atmosphere, the Ecoinvent Excel files "13_MSWLFv2.xls" and "13_MSWIv2.xls" have to be modified. These two files contain the inventoried data of the disposal of different waste materials into sanitary landfills. These files can be modified to simulate 100% of landfill gas emissions to the atmosphere. The process of how to modify these files is available in Appendix D.

6.3.2.2 *Modelling open dumps based on sanitary landfills*

The environmental ministry of Peru, MINAM, estimated for the year 2009 a total of 18 illegal open dumps only in the city of Lima (MINAM 2010b). Open dumps are unconditioned spaces where different waste types are disposed illegally. These open dumps normally do not count with a bottom liner to avoid infiltrations, leachate collection and treatment, or landfill gas collection and burning (Abarca Guerrero et al. 2013).

These spaces have enormous environmental and social impacts, like water and air contamination, release of bad odours, attraction of dangerous vectors (e.g. rats), and so on. These impacts vary according to different factors, such as type of waste disposed, type of soil, proximity of water bodies or directly disposed in water bodies, proximity of population. These factors make it really difficult to predict how an open dump will impact the environment.

For this case study, an estimation of the possible impacts of plastics waste in open dumps is done by extracting the untreated emissions of potentially generated leachates and gases on a sanitary landfill. The Ecoinvent Excel files "13_MSWLFv2.xls" and

"13_MSWIv2.xls" are used to obtain this information and the process of how the information is extracted is available in Appendix D.

6.3.2.3 *Modelling incineration including electricity as co-product*

In the second scenario, SC2, the incineration of 100% of MPW is assumed. For this scenario, the Ecoinvent processes of disposal of plastics to municipal incineration are used. In Ecoinvent, the generated electricity by incineration of plastics is assumed to be available for free. Thus, the environmental impacts generated are allocated 100% on the incineration process alone. This full allocation of all the generated impacts to the incineration process means that the produced electricity is virtually free of any impacts (Doka 2009).

In this study, it is assumed that the electricity generated by the incineration of MPW is going to be inserted in the national electricity mix and sold in the electricity market. To do this, the potential electricity generated by the incineration of 1000 kg of MPW is calculated. The Excel "13_MSWIv2.xls", under the (hidden) sheet "energy", shows per type of plastic the energy generated during municipal incineration and subtracts the energy that the whole process uses. The remaining energy is inserted in the unit process as an output of the process. The calculations are shown in Appendix D.

6.3.2.4 *Modelling of mechanical recycling*

The platform SIGERSOL contains information from 2015 about the different plastic fractions available in Lima, per municipality. Table 6-1 shows the average fractions of PET bottles, hard plastics and plastic bags, which are the only available classifications for the MPW in the mentioned platform.

The classifications "plastic bags" and "hard plastics" do not include a description of the fraction composition (e.g. PE, PP, PS, PVC). In this study, plastic bags are assumed to be composed by LDPE plastics. Also, plastics considered as hard plastics are assumed to be composed by PE, PS, PP and PVC fractions. For this case study, it is assumed that the four fractions are present in equal amounts (Figure 6-4). Because of the big differences within the composition of MPW among the selected studies during the systematic review, it is not possible to depict an average composition to be used in this case study (see Table 5-3).

During the sorting and recycling phases of scenario SC3, plastics that cannot be sorted and losses from recycling are considered as "plastic mixture" and are assumed to be transferred to an incineration plant. For the incineration of "plastic mixture", the Ecoinvent processes "disposal, plastics, mixture, 15.3% water, to municipal incineration" is considered. The process "manual separation" is assumed to increase the separation efficiency of plastic waste going to mechanical recycling to 95%.

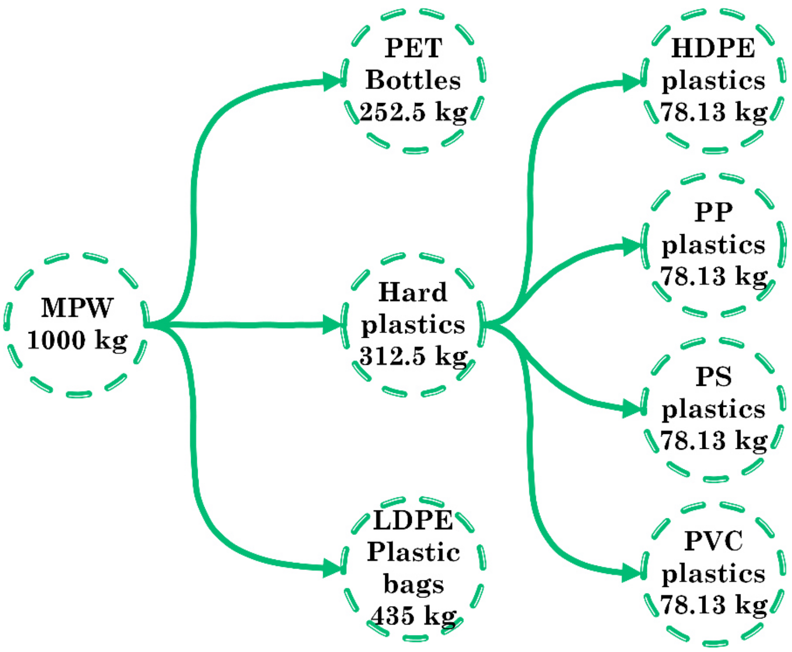
Also, it is assumed that all the included processes in SC3 after collection occur inside the same location and there is no need of more transport of the waste between the stages.

Table 6-1: Results of characterization of MSW in 48 municipalities in Lima – Source: SIGERSOL

Plastic type	PET bottles	Hard plastics	Plastic bags	% of MPW in MSW
Fraction of the total MSW (average) % *	2.7	3.3	4.6	10.6
Fraction of the total MPW %	25.3	31.3	43.5	100

* Information collected from 48 municipalities in Lima

Figure 6-4: Polymer composition of plastic fractions in MPW in Lima (kg per 1000 kg of MPW)



6.3.3 Multifunctionality and allocation

A unit process yielding more than one functional flow is defined as a "multifunctional process". In this definition, a functional flow is any of the flows of a unit process consisting its goal, viz. goods/products produced by a process of waste inflows managed by a waste treatment process (Guinee et al 2004). The scenarios SC2 and SC3, developed in this case study, process waste inflows and generate by-products during the incineration and recycling stages (i.e. electricity, recycled pellets). These are thus multifunctional processes that need a solution.

As baseline, the multifunctional processes of SC2 and SC3 are solved by economic allocation. To evaluate the effects on the results of choosing economic allocation, several sensitivity analyses are performed in addition. Solving multifunctionality by partitioning is only one of many solutions, that tries to separate one function in a process that generates more than one function.

To solve the multifunctionality, first we need to determine which flows are functional flows in the system under study. As mentioned above, a functional flow can be either a product (good) produced by a process or waste treated by a process. To differentiate between goods and wastes, economic values of the selected flows can be used. When a flow has a negative economic value, it is considered as a waste, and when it has a positive economic value (i.e. price) it is considered a good.

After the functional flows are identified, all the other non-functional flows need to be allocated to the identified functional flows. To do this, the shares of each functional flow in the total proceeds is used. After the allocation is done, all non-functional flows are allocated to the functional ones, thus if all the amounts allocated to each mono functional process are added up, the original quantity of each specific flow is obtained (Guinée et al. 2004).

In this case study, the processes of "incineration of MPW" in scenario SC2, "sorting and recycling of MPW" and "incineration of losses and unsorted plastics" in scenario SC3 are considered as multifunctional processes. In these processes, a waste enters the process with a negative economic value, and a good leaves the process, with a positive economic value, which represent cases of open-loop recycling processes.

The functional flows in these processes and their corresponding economic values are listed in Table 6-2. The physical amount (quantity) of the functional flows that enter the processes as inputs are represented by a negative number, and the ones that leave the processes as outputs by a positive number. Costs are represented by negative numbers in red (for waste) and sale prices are represented by positive numbers in black (for goods). The allocation factors that are used to calculate the amount of impacts that are allocated to each functional flow are also calculated and shown in the last column.

Table 6-2: Functional flows, economic values and allocation factors of multifunctional processes

Process	Funtional flow	Quantity	Economic value	Unit	Proceeds	Allocation factor
SC2 Incineration of MPW	SC2 transferred MPW	-1000 kg	-0.0083	USD/kg [a]	8.3	0.04
	SC2 electricity from waste	1116 kWh	0.17	USD/kWh [b]	189.7	0.96
				Total proceeds	**198.0**	
SC3 Sorting and mechanical recycling of MPW	SC3 Separated MPW	-855 kg	-0.0083	USD/kg [a]	7.1	0.01
	SC3 PET pellets	216 kg	1.26	USD/kg [c]	272.2	0.36
	SC3 PP pellets	66.8 kg	1.04	USD/kg [c]	69.5	0.09
	SC3 PS pellets	66.8 kg	1.5	USD/kg [c]	100.2	0.13
	SC3 HDPE pellets	66.8 kg	1.14	USD/kg [c]	76.2	0.10
	SC3 LDPE pellets	372 kg	0.49	USD/kg [c]	182.3	0.24
	SC3 PVC pellets	66.8 kg	0.77	USD/kg [c]	51.4	0.07
				Total proceeds	**758.8**	
SC3 Incineration of losses and unsorted plastics	SC3 losses and unsorted MPW	-145 kg	-0.0083	USD/kg [a]	1.2	0.05
	SC3 electricity from waste	140 kWh	0.17	USD/kWh [b]	23.8	0.95
				Total proceeds	**25.0**	

[a] Source: MINAM 2009
[b] Source: RPP Noticias 2016
[c] Source: Plastic News 2017

The cost of the MPW and the losses from recycling are based on the actual costs of the current disposal alternative, sanitary landfill. The costs of the disposal of one tonne of MPW in a sanitary landfill in Lima is 28 PEN[2] (MINAM 2009) or 8.3 USD.

The electric energy in Peru has different rates according to the type of energy required (e.g. high voltage, low voltage) and type of electric power. The prices go from 0.20 PEN/kWh in off-peak hours and 1.50 PEN/kWh in peak hours (OSINERGMIN 2017). Considering an average of the available tariffs for electricity in Lima, the price of the electricity generated by the incineration of MPW is assumed to be 0.60 PEN/kWh or 0.17 USD/kWh. The electricity generated is assumed to be inserted as part of the electricity mix in Lima, which consists of 50% from hydropower and 50% from thermoelectric plants using natural gas (SNMPE 2016).

The prices of recycled plastic pellets are taken from the webpage "Plastic News", which includes the latest prices for recycled plastics in USD cents per pound (Plastics News 2017). The prices correspond to the ones available on January 30th of 2017.

6.4 Impact assessment

6.4.1 Impact categories

In this study, the impact assessment follows an environmental midpoint problem orientation. Hence, baseline mid-point of the cause-effect chain categories, from the family of methods CML2001 Baseline, are selected (Guinée et al. 2002; Guinée and Heijungs 2005) and are listed in Table 6-3. As specified by ISO 14044 (2006), for comparative evaluations using LCA intended for public disclosure a "sufficiently comprehensive set of category indicators" must be selected. Following the list of baseline impact categories suggested to be included in LCA studies by the Handbook on Life Cycle Assessment (Guinée et al. 2002), nine category indicators are selected for this

[2] PEN is the abbreviation of Peruvian Sol, the currency of Peru. 1 PEN is equivalent to 0.29 $.

case study, considering their environmental relevance and their international acceptance.

It is important to mention that the toxic impact categories of the different existing methods have bigger uncertainties compared to the non-toxic categories. The non-toxic impact categories (i.e. eutrophication, resource depletion, acidification, photochemical oxidation, climate change and stratospheric ozone depletion) have better established characterization factors and more accepted concepts (Rigamonti et al. 2014).

Table 6-3: Selected impact categories and characterization factors

Impact Category	Characterization factor	Unit of indicator result
eutrophication	**EP:** eutrophication potential for each eutrophying emission to air, water and soil	kg PO_4-eq
resource depletion	**ADP:** abiotic depletion potential for each extraction of minerals and fossil fuels	kg antimony eq
acidification	**AP:** acidification potential for each acidifying emission to the air	kg SO_2-eq
photochemical oxidation	**POCP:** photochemical ozone creation potential for each emission of VOC or CO to the air	kg ethylene-eq
climate change	**GWP100:** global warming potential for a 100-year time horizon for each greenhouse gas emission to the air	kg CO_2-eq
stratospheric ozone depletion	**ODP:** ozone depletion potential in the steady state for each emission to the air	kg CFC-11-eq
terrestrial ecotoxicity	**TAETP:** terrestrial ecotoxicity potential for each emission of a toxic substance to air, water and/or soil	kg 1,4-DCB-eq
freshwater aquatic ecotoxicity	**FAETP**: freshwater aquatic ecotoxicity potential for each emission of a toxic substance to air, water and/or soil	kg 1,4-DCB-eq
human toxicity	**HTP:** human-toxicity potential for each emission of a toxic substance to air, water and/or soil	kg 1,4-DCB-eq

Source: Guinée et al. 2002

The classification step assigns all the interventions resulting from the inventory analysis to the previously selected impact categories (Guinée, et al. 2002). The classification is done automatically by the CMLCA program and the results are shown in the following sections.

6.4.2 Characterization results

The characterization results of the three scenarios are presented in Table 6-4 and illustrated in Figure 6-5, comparing the scenarios relative to the largest value. The baseline scenario SC1, (75% of MPW landfilled and 25% of MPW disposed in open dumps) results in higher environmental impacts on all the impact categories selected, compared to the scenarios SC2 (100% of MPW incinerated) and SC3 (85.5% of MPW recycled and 14.5% of MPW incinerated).

Also, for all the impact categories selected, scenario SC3 (85.5% of MPW recycled and 14.5% of MPW incinerated) shows a better environmental performance compared to the scenario SC2 (100% incineration of MPW) and the baseline scenario SC1.

The biggest reductions in environmental impacts of the alternative scenarios SC2 and SC3, compared to the baseline scenario, are observed for eutrophication, photochemical oxidation, and terrestrial, freshwater and human ecotoxicity. In the case of climate change, important reductions are observed for the recycling scenario SC3, with around 50% less GHG emissions to the environment. The incineration of MPW in SC2, generates GHG emissions, increasing the potential impacts on climate change. Still, SC2 presents a better environmental performance, compared to the baseline scenario SC1.

In the case of acidification, resource depletion and stratospheric ozone depletion, the three scenarios show similar characterization results. This is because the main contributors to these impact categories are the stages of collection and transportation. In the case of acidification, it is related to the emissions of nitrogen oxides (NO_x) and sulfur dioxides (SO_2). For stratospheric ozone depletion, the impacts are related to the production of crude oil (diesel) used in those stages. Finally, in the case of resource depletion, the impacts are related also to the use of crude oil and the use of natural gas for the production of electricity.

Based on the systematic review reported in chapter 5, it was expected that the recycling scenario SC3 would emerge as a better option when compared with the baseline scenario SC1 and the incineration scenario SC2. The reviewed studies during the systematic review revealed that in all cases the recycling scenario presented a better environmental performance when compared to a landfill scenario or an incineration scenario.

On the other hand, in relation to the climate change category it was expected that the incineration scenario SC2 would be less preferable to the baseline scenario as mentioned by Shonfield (2008). However, the results obtained for this case study showed that scenario SC2 is environmentally preferable to scenario SC1 in all selected impact categories. It is important to mention that this case study, unlike the evaluated studies during the systematic review, solves the multifunctionality problem with economic allocation and not with substitution method. Also, in this case study it is assumed that all the landfill gases (LFG) are directly emitted to the atmosphere without any previous treatment, which is not the case in Shonfield's study.

Another important difference between the results of this case study and the evaluated studies during the systematic review is that in this case SC3 appeared to be preferable for all selected impact categories. As mentioned before, only two studies, Rigamonti et al. (2014) and Shonfield (2008), included seven impact categories in their evaluation, and both studies did not obtain a scenario that showed a better environmental performance for all selected categories. Nevertheless, it is important to mention that these results are influenced by the selected method to solve multifunctionality and all the assumptions mentioned before. To evaluate the effects of these decisions for the case study results, an extensive sensitivity analysis is performed later in section 6.5.3.

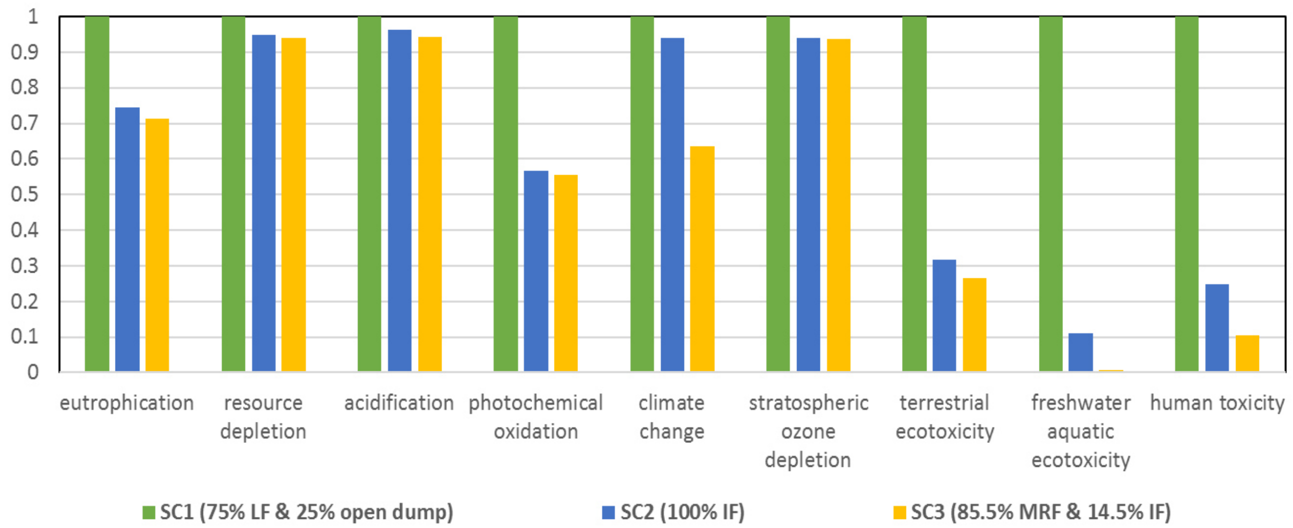
Table 6-4: Comparison of characterization results for the three scenarios

Impact category	SC1 (75% LF & 25% open dump)	SC2 (100% IF)	SC3 (85.5% MRF & 14.5% IF)	Unit
eutrophication	0.292	0.217	0.208	kg PO4-eq
resource depletion	1.57	1.49	1.48	kg antimony-eq
acidification	0.964	0.928	0.909	kg SO2-eq
photochemical oxidation	0.0664	0.0376	0.0369	kg ethylene-eq
climate change	365	342	232	kg CO2-eq
stratospheric ozone depletion	3.56E-05	3.35E-05	3.34E-05	kg CFC-11-eq
terrestrial ecotoxicity	0.797	0.252	0.211	kg 1,4-DCB-eq
freshwater aquatic ecotoxicity	1100	121	6.38	kg 1,4-DCB-eq
human toxicity	441	109	46.2	kg 1,4-DCB-eq

Indicates the higher value from the three scenarios

Indicates the lower value from the three scenarios

Figure 6-5: Characterisation results relative to the largest value for the three scenarios

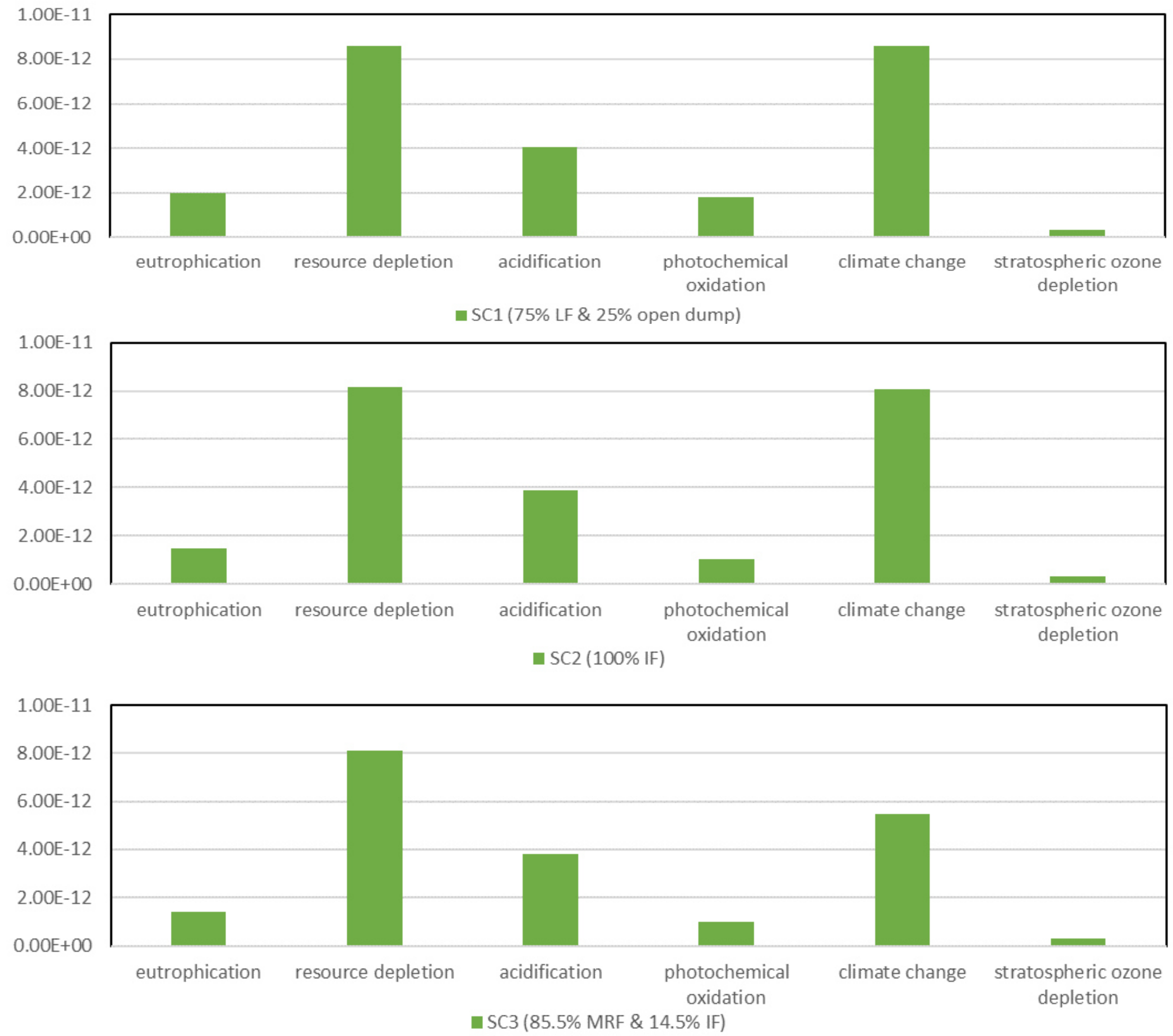


6.4.3 Normalization results

Normalization results are presented in Figure 6-6 for the three scenarios. The normalized results of the impact categories terrestrial, freshwater and human toxicity are not shown in the graphs. For these categories, the normalized results are affected by huge data gaps leading to inconsistently large numbers.

These results for the rest of non-toxic impact categories show that for the three scenarios, the contribution to the environmental impacts of stratospheric ozone is negligible, and the contribution from resource depletion, climate change and acidification is more significant.

Figure 6-6: Normalised indicator results for the three scenarios



6.4.4 Interventions without characterisation factors

For the three scenarios, 758 of the calculated interventions in the inventory analysis are lacking characterization factors. This means that these emissions, generated during the management of MPW in all scenarios, are not being considered in the characterization results. It is important to mention that among these interventions without characterization factors, there are some potentially hazardous chemicals like cyanides and chlorides compounds that are not being considered. Only the interventions that are associated to the nine impact categories selected for this case study (section 6.4.1) are included in the characterization results.

6.5 Interpretation

6.5.1 Consistency and completeness

The aim of this section is to evaluate if the assumptions made and data collected are consistent with the described goal and scope of the study. Also in this section, the completeness of all relevant data and processes is evaluated.

The collection of data started with the systematic review of selected scientific reports of LCA of MSW and/or MPW management. This phase is extensively described in section 5. From the selected articles, data is retrieved considering mainly the availability of unit process data and transparent reporting of used data. These retrieved data are used for the processes of collection, compaction, transfer and mechanical recycling. The reference sources are mainly related to developed countries, which means that the data is not completely representative of the Peruvian situation.

The collection of specific data related to the mechanical recycling operations that exist in Peru could not be obtained, as not being available for the public. For the recycling process, data collected from the systematic review is used instead. This data is modified according to the available information of the existing characteristics of the MPW in Lima, Peru. The characterization of MPW in Lima is available for 48 out of 50 existing municipalities in the SIGERSOL platform. The types of plastics specified in the platform are divided in three groups: PET plastics, plastic bags and hard plastics. For this case study, plastic bags are assumed to be LDPE plastics, and hard plastics are assumed to be composed by HDPE, PVC, PS and PP fractions in equal amounts. The accuracy of this assumption regarding reality cannot be checked because of lack of real data, but it is assumed that the effects of the proportions on the results are negligible. All data assumptions, adaptations and sources are available in Appendix B

6.5.2 Contribution analysis

A contribution analysis is performed to evaluate the contribution of the different stages in each scenario to the total environmental impact per impact category selected. This analysis permits the identification of hotspots and more relevant stages in relation to their impacts. The data used to develop the tables and graphs presented in this section is available in Appendix E.

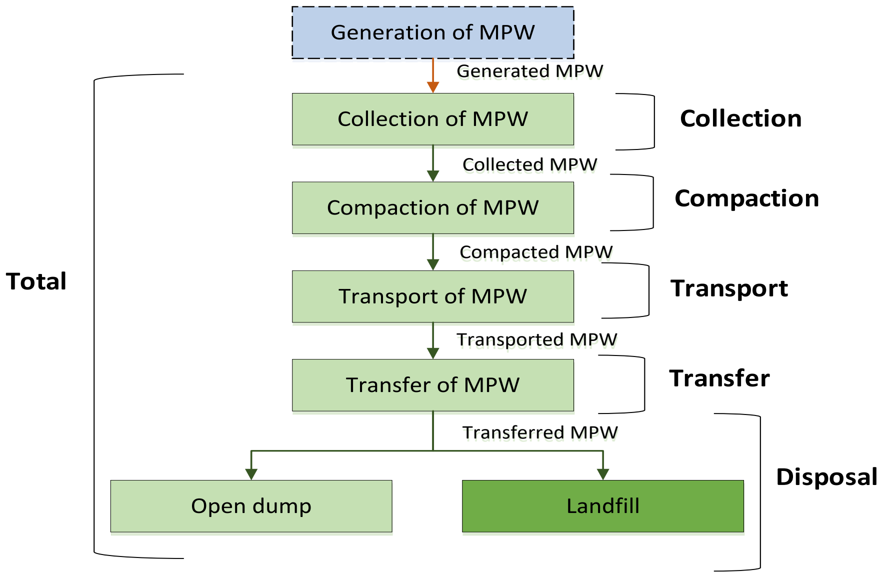
6.5.2.1 *Contribution analysis in scenario SC1*

Following the flow diagram presented in Figure 6-1, the contribution analysis is performed based on the different stages considered during the modelling of the baseline scenario SC1. Figure 6-7 shows the selected stages for the contribution analysis in SC1.

As shown in Table 6-5 and Figure 6-8, the disposal of MPW in landfills (75%) and open dumps (25%) contribute to more than 50% of the total environmental impact in the categories of climate change, photochemical oxidation, terrestrial and freshwater ecotoxicity and human toxicity.

In the case of climate change category, the impacts are mainly related to the emissions of methane (CH_4) and carbon dioxide (CO_2) from landfills, open dumps and from the transport of the MPW. Also, the category photochemical oxidation, is mainly related to the emissions of CH_4.

Figure 6-7: Stages in scenario SC1 - baseline



For terrestrial ecotoxicity, the impacts are mainly related to the emission of mercury, in the long-term from landfills. Similarly, freshwater ecotoxicity and human toxicity impacts are related to the emissions of heavy metals in the long-term from landfills.

In the case of the eutrophication category, disposal in landfills and open dumps represents almost 50% of the total impact. The eutrophication in this scenario is related to the emissions of ammonia (NH_4) and nitrites (NO_2) from the disposal in landfills, and to the emissions of nitrate oxides (NO_x) from the transport of MPW. Also, the impacts of the extraction and production of diesel used during the collection and compaction stages increase the total eutrophication impact.

For the categories of resource depletion, acidification and stratospheric ozone depletion, the impacts of the disposal phase are 10% or less of the total impact. The resource depletion is mainly related to the extraction and production of diesel used in the collection and compaction stage, and the use of natural gas in the stages of compaction and transfer. The acidification results is mostly related to the emissions of NO_x and sulfur dioxide (SO_2) from the transport and extraction and production of the diesel used in the collection and compaction stage.

In the case of the stratospheric ozone depletion results, the impact is mostly related to the emission of Halon 1301 ($CBrF_3$), during the extraction and production of diesel, and

Halon 1211 ($CBrClF_2$), during the production of electricity from natural gas. These two compounds are used for fire suppression and refrigeration and are known as responsible for ozone depletion.

Plastics have a slow degradation rate in the environment. According to Doka (2009), the estimate of plastic degradation in a sanitary landfill during the first 100 years is only 1%. Ecoinvent process of sanitary landfill includes all potential emissions from landfills, in the long- and short-term in the impact assessment, treating them as short-term emissions. This brings big uncertainties to the calculations, since these numbers are based on assumptions and periods of time of 60'000 years.

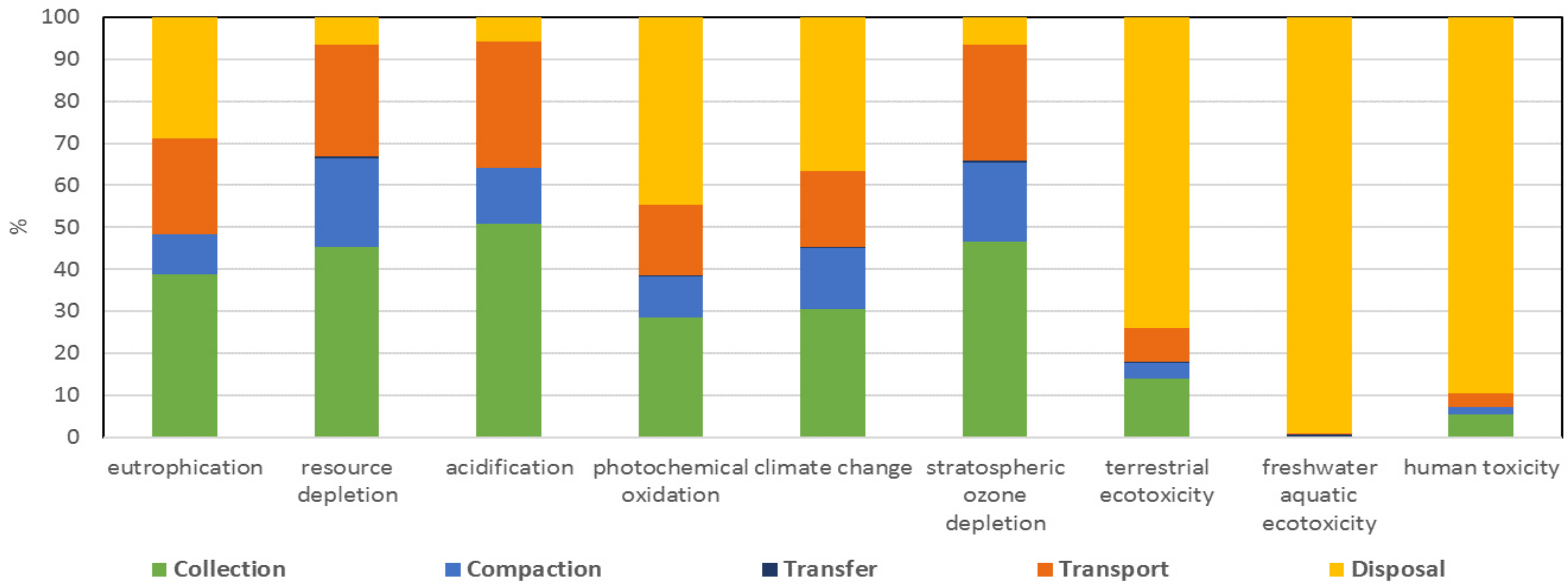
In the case of open dumps, using the Ecoinvent process of sanitary landfill, and the datafile "13_MSWLFv2.xls" from Ecoinvent (2010) and Doka (2008), the short-term emissions (100 years) of landfill gases and leachate is calculated for plastic waste. This is only a rough estimate of possible emissions of MPW dumped in open areas. The real impact of plastic waste in the environment and, especially, in water bodies (rivers and sea) is not included in these results because of lack of data. This exclusion makes the calculated impacts an underestimation of the real potential environmental impacts.

It is important to highlight that landfills will still be necessary, since not all waste materials can be recycled or incinerated. Thus, it is important that the existing landfills in Lima, and in Peru, are properly designed and managed. It is recommended that landfills are located far from human settlement and that they are properly covered and sealed to avoid contaminants entering the surrounding environment.

Table 6-5: Contribution of each stage per impact category for SC1

Impact category	Collection	Compaction	Transfer	Transport	Disposal	Total	Unit
eutrophication	0.11	0.028	0.0004	0.066	0.084	0.292	kg PO4-eq
resource depletion	0.71	0.33	0.007	0.42	0.102	1.57	kg antimony-eq
acidification	0.49	0.13	0.0006	0.29	0.06	0.96	kg SO2-eq
photochemical oxidation	0.02	0.01	0.0002	0.01	0.03	0.066	kg ethylene-eq
climate change	111	53	1.4	65.6	134	365	kg CO2-eq
stratospheric ozone depletion	1.7E-05	6.7E-06	1.6E-07	9.8E-06	2.3E-06	3.6E-05	kg CFC-11-eq
terrestrial ecotoxicity	0.11	0.031	0.0006	0.065	0.589	0.797	kg 1,4-DCB-eq
freshwater aquatic ecotoxicity	0	0	8.08	1.92	1090	1100	kg 1,4-DCB-eq
human toxicity	24	8	0.1	13.9	395	441	kg 1,4-DCB-eq

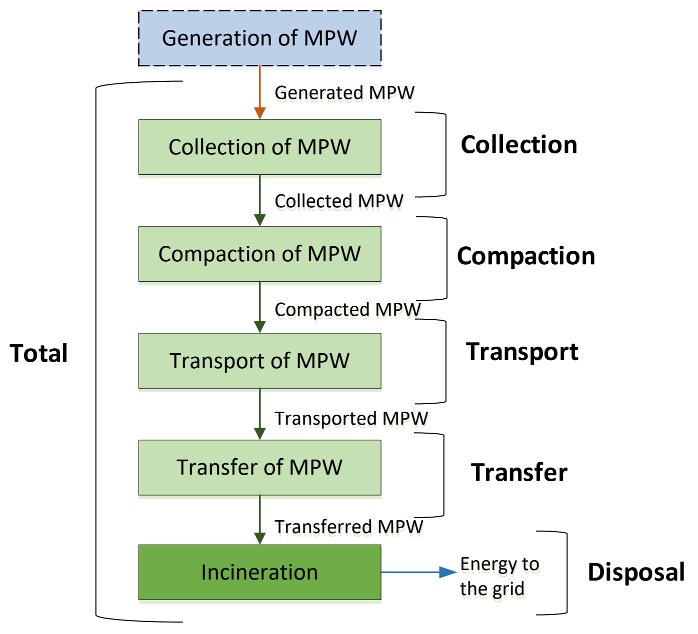
Figure 6-8: Contribution of each stage per impact category for SC1



6.5.2.2 *Contribution analysis in scenario SC2*

Following the flow diagram presented in Figure 6-2, the contribution analysis is performed based on the different stages considered during the modelling of the scenario. Figure 6-9 shows the selected stages for the contribution analysis in SC1.

Figure 6-9: Stages in scenario SC2



In this scenario, it is assumed that all the MPW is separated and sent to a municipal incinerator. As observed in Table 6-6 and Figure 6-10, the environmental impact categories of eutrophication, resource depletion, acidification, photochemical oxidation and stratospheric ozone depletion, are mainly driven by the stages of transport, collection and compaction of MPW.

In the case of eutrophication, the impacts are mainly related to the emissions of nitrogen oxides (NO_x) during the transport phase and for the use of diesel during collection and compaction phases, and other impacts related to the extraction and refinery of diesel.

The resource depletion is mainly related to the extraction and production of diesel used in the collection and compaction stage, and the use of natural gas in the stages of compaction and transfer.

The impacts on acidification are related to the emissions of nitrogen oxide (NO_x) and sulfur dioxide (SO_2) gases to the atmosphere, both because of transportation of waste and extraction and production of diesel used in the stages of collection and compaction.

For photochemical oxidation, the impacts are related to the emissions of carbon monoxide (CO) and sulfur dioxide (SO_2) as a result of the transport of waste and extraction and production of diesel, used in the stages of collection and compaction.

In the case of the stratospheric ozone depletion results, the impact is mostly related to the emission of Halon 1301 ($CBrF_3$), during the extraction and production of diesel, and Halon 1211 ($CBrClF_2$), during the production of electricity from natural gas.

In the case of terrestrial ecotoxicity, only 20% of the impact is attributed to the incineration of plastics, and the rest is mostly attributed to collection and transport. The incineration of plastics, especially PVC fractions, could release to the atmosphere mercury and vanadium, which causes terrestrial ecotoxicity impacts. Also, the extraction and refinery of diesel, could release mercury, vanadium and other heavy metals, attributable to this impact category.

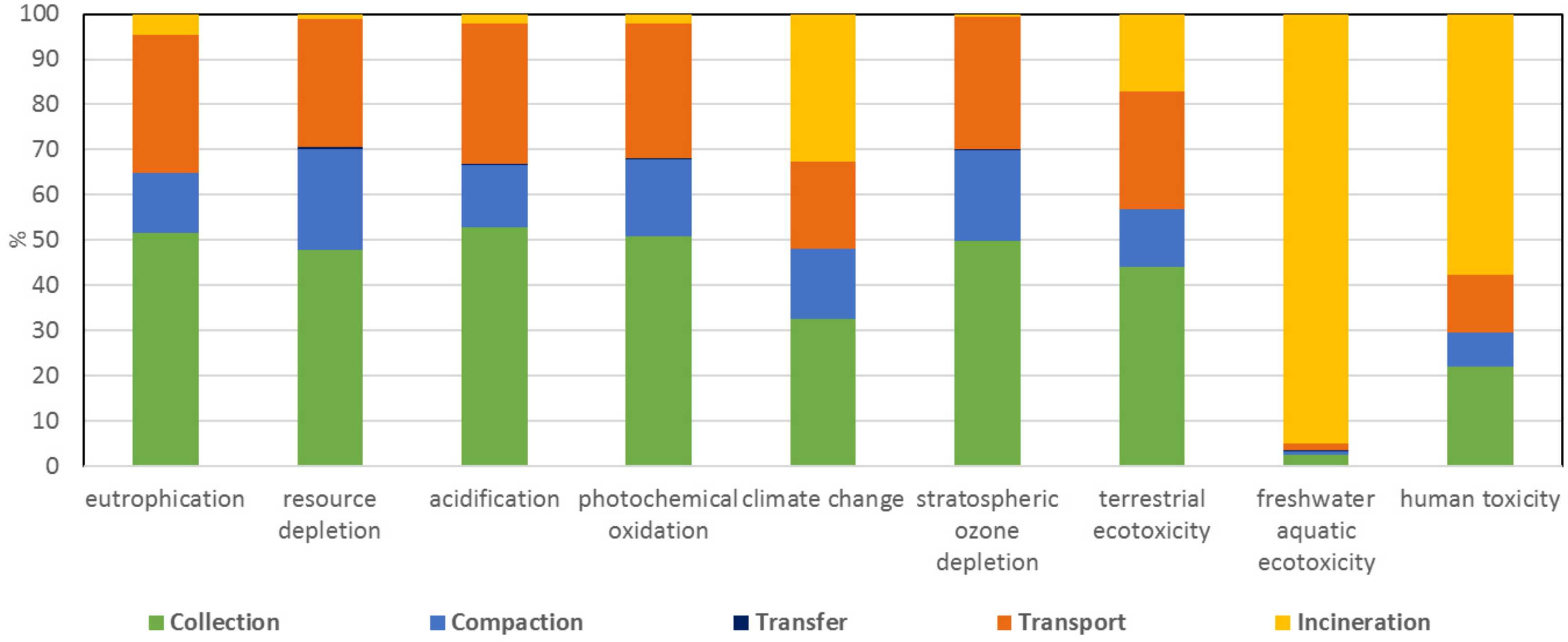
For the category of climate change, half of the impacts are related to the stage of disposal by incineration of plastics, followed by the stages of transport and compaction. The impacts are mostly related to the emissions of carbon dioxide (CO_2) from the combustion of plastics and transport of waste.

Finally, freshwater ecotoxicity and human toxicity impacts are mostly related to the incineration stage, with 98% and 70%, respectively, of the potential impacts. The impacts on freshwater ecotoxicity are mainly related to the emissions of vanadium during the combustion of plastics, mainly PET, PP and PE fractions. In the case of human toxicity, the impacts are also related to the emissions of vanadium and other heavy metals (e.g. antimony).

Table 6-6: Contribution of each stage per impact category for SC2

Impact category	Collection	Compaction	Transfer	Transport	Incineration	Total	Unit
eutrophication	0.11	0.03	0.0002	0.07	0.01	0.217	kg PO4-eq
resource depletion	0.71	0.33	0.007	0.42	0.02	1.49	Kg antimony-eq
acidification	0.49	0.13	0.001	0.29	0.02	0.928	kg SO2-eq
photochemical oxidation	1.9E-02	6.4E-03	1.1E-04	1.1E-02	7.9E-04	3.8E-02	kg ethylene-eq
climate change	111	53	0.4	65.6	112	342	kg CO2-eq
stratospheric ozone depletion	1.7E-05	6.7E-06	8.2E-08	9.8E-06	2.1E-07	3.4E-05	kg CFC-11-eq
terrestrial ecotoxicity	0.11	0.03	0.0004	0.065	0.043	0.252	kg 1,4-DCB-eq
freshwater aquatic ecotoxicity	3	1	0.08	1.9	115	121	kg 1,4-DCB-eq
human toxicity	23.9	8.2	0.1	13.9	62.9	109	kg 1,4-DCB-eq

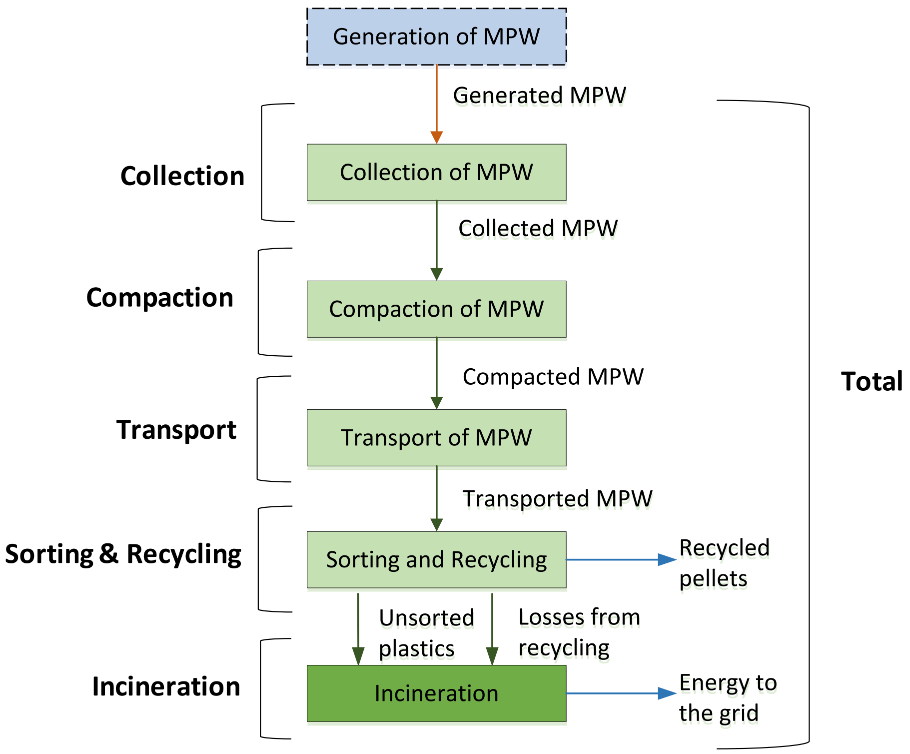
Figure 6-10: Contribution of each stage per impact category for SC2



6.5.2.3 *Contribution analysis in scenario SC3*

Following the flow diagram presented in Figure 6-3, the contribution analysis is performed based on the different stages considered during the modelling of the scenario. Figure 6-11 shows the selected stages for the contribution analysis in SC2.

Figure 6-11: Stages in scenario SC3



This scenario is based on the mechanical recycling of plastic waste to produce recycled pellets and the incineration of unsorted plastics and recycling losses. In this scenario, it can be seen that the impacts of sorting and mechanical recycling are minimal representing between 0.2% and 2% of the total generated impact in all the selected categories. Similarly, the incineration of unsorted plastics and losses from recycling also represents a small fraction of the total impact, varying from 0.0008% to 0.12% of the total impact.

The contribution analysis is an important step in the evaluation of the characterization results. Developing a contribution analysis of the different phases of a system could bring erroneous results if economic allocation is used as the method for solving multifunctional problems.

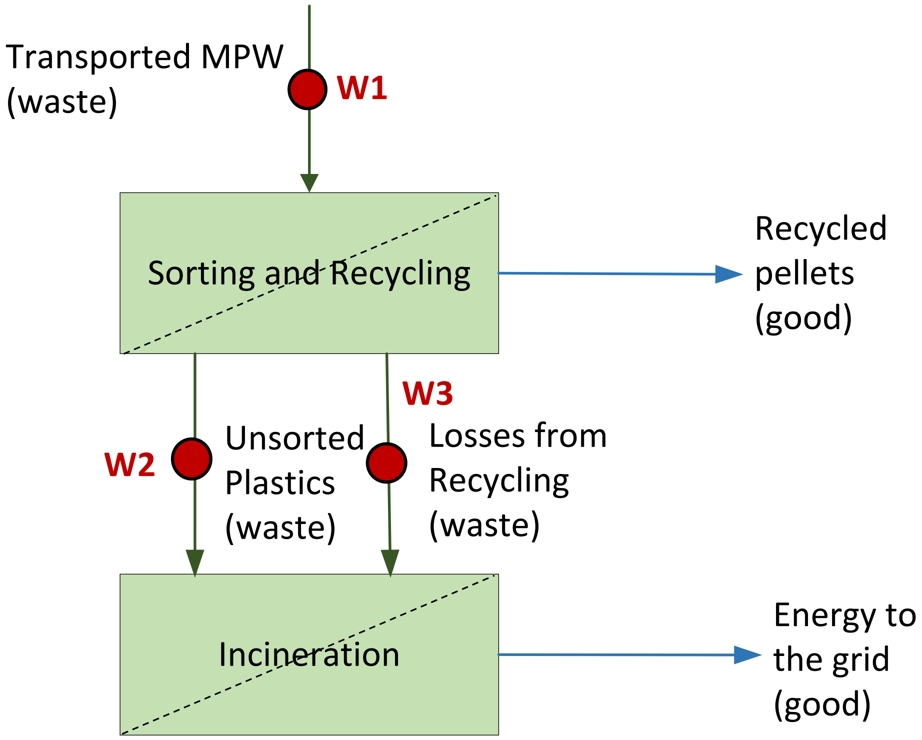
The sorting and mechanical recycling phase converts a waste into a good (i.e. recycled plastic pellets) and generates residual wastes (i.e. unsorted plastics and losses from recycling) to be incinerated in a next phase. Based on the proceeds calculated in Table 6-2, an economic allocation is performed to allocate non-functional flows (generated wastes for incineration and impacts) of the sorting and mechanical recycling process to the MPW and the recycled plastic pellets.

The unsorted plastics and losses from recycling are incinerated in a municipal incinerator, following the same assumptions as in scenario SC2. The electricity produced in the incinerator leaves the system as a good, converting the process also into a multifunctional process. Following the selected proceeds in Table 6-2, an economic allocation is performed as well.

To calculate only the impacts of the "sorting and recycling" phase, the impacts of the incineration of the plastic losses need to be separated from the total impacts of the sorting recycling phase, which also includes the treatment of the losses from recycling. A representation of this procedure is shown below in Figure 6-12. In this figure, the dashed lines represent the partitioning of the environmental impacts among the processed waste and the resulting good. The red dots represent the inflow of waste material into the multifunctional processes, which are the functional flows under study.

At first glance, the impacts of the "sorting and recycling" phase are represented by the impacts of treating the transported MPW "W1" without including the impacts of treating the unsorted plastics "W2" and the losses from recycling "W3", which are part of the impacts of the "incineration" phase. However, if the mentioned subtraction of the impacts of "W1" minus the impacts of "W2" and "W3" is performed, negative numbers for the "sorting and recycling" stage are obtained. These negative numbers should not be possible, since the method chosen for solving multifunctionality is partitioning by economic allocation.

Figure 6-12: Procedure to calculate the contribution of the phases sorting and recycling, and incineration to the total environmental impact in SC3



The negative numbers are a result of double counting (or double subtracting) the total impacts of incinerating "W2" and "W3" wastes. During the economic allocation of the impacts of "sorting and recycling" between the functional flows "W1" transported MPW and the recycled pellets (good), all the non-functional flows, including "W2" and "W3", are allocated to each functional flow. This means that a part of the impacts of incinerating "W2" and "W3" are already allocated to the functional flow of recycled pellets (good) that leave the system boundaries and should no longer be evaluated as part of W1 system.

To avoid this double counting, the amount in weight of "W2" and "W3" that is allocated to the functional flow "W1" needs to be calculated and used to calculate the impacts of incineration that are attributed to these quantities. To calculate these amounts, the allocation factor of each functional flow (i.e. W1 and recycled pellets (good)) needs to be calculated first. Table 6-7 shows the calculations of these factors and Table 6-8 shows the calculations of the physical weights (in kg) of "W2" and "W3" attributed to the functional flow "W1".

Table 6-7: Allocation factors for the process of sorting and recycling of MPW

Functional flows	Quantity (kg)	Price (USD/kg)	Proceeds (USD)	Allocation factor
W1 Transported MPW	-1000	-0.0083	8.3	0.011
Recycled pellets (good)	855	0.88 [a]	751.7	0.989

[a] Weighted average of prices for recycled pellets

Table 6-8: Un-allocated and allocated flows for the multifunctional process of sorting and recycling of MPW

Flows	Multifunctional Sorting and recycling	Mono-functional W1 Transported MPW	Mono-functional Recycled pellets (good)
W2 unsorted plastics	50	0.55	49.45
W3 losses from recycling	95	1.04	93.96
W1 Transported MPW	-1000	1000	0
Gtotal - All goods	855	0	855

As observed in Table 6-8, the amount of "W2" unsorted plastics and "W3" losses from recycling allocated to the functional flow "W1" transported MPW are small, being only 0.55kg for "W2" and 1.04kg for "W3". After calculating these weights, the impacts of incineration of both wastes "W2" and "W3" can be calculated and subtracted from the total impacts of managing "W1" transported MPW, to obtain the contribution of the "sorting and recycling" phase, and the contribution of the "incineration" phase.

Table 6-9 and Figure 6-13 show the environmental impacts of each stage for all the selected impact categories. Here it can be observed that the environmental impacts are mainly driven by the stages of collection, compaction and transport of MPW.

Eutrophication is related mainly to the emissions of nitrogen oxides (NO_x) during the transport phase and for the extraction and production of diesel, used during the collection and compaction phases.

The resource depletion is mainly related to the extraction and production of diesel used in the collection and compaction stage, and the use of natural gas in the stages of compaction and transfer.

A similar situation is observed for the acidification category, where the impacts are related to the emissions of nitrogen oxides (NO_x) and sulfur dioxide (SO_2) gases to the atmosphere, both because of transportation of waste and the extraction and production of diesel used in the stages of collection and compaction.

Photochemical oxidation is related to the emissions of carbon monoxide (CO) and sulfur dioxide (SO_2) also from the stages of collection, compaction and transport of waste.

In the case of the stratospheric ozone depletion results, the impact is mostly related to the emission of Halon 1301 ($CBrF_3$), during the extraction and production of diesel, and Halon 1211 ($CBrClF_2$), during the production of electricity from natural gas.

Terrestrial ecotoxicity is related mainly to the emissions of heavy metals, like vanadium, mercury, chromium and chromium VI. These emissions are a result of the extraction and refinery of diesel, used in the stages of collection, compaction and transport.

Global warming is related, in this scenario, to the emissions of carbon dioxide (CO_2) during the transport of waste, production of electricity from natural gas, and during the incineration of plastic losses from the sorting and recycling stage. The impacts are also related to the emissions of GHG during the extraction of diesel and production of hydropower electricity, in a minor way.

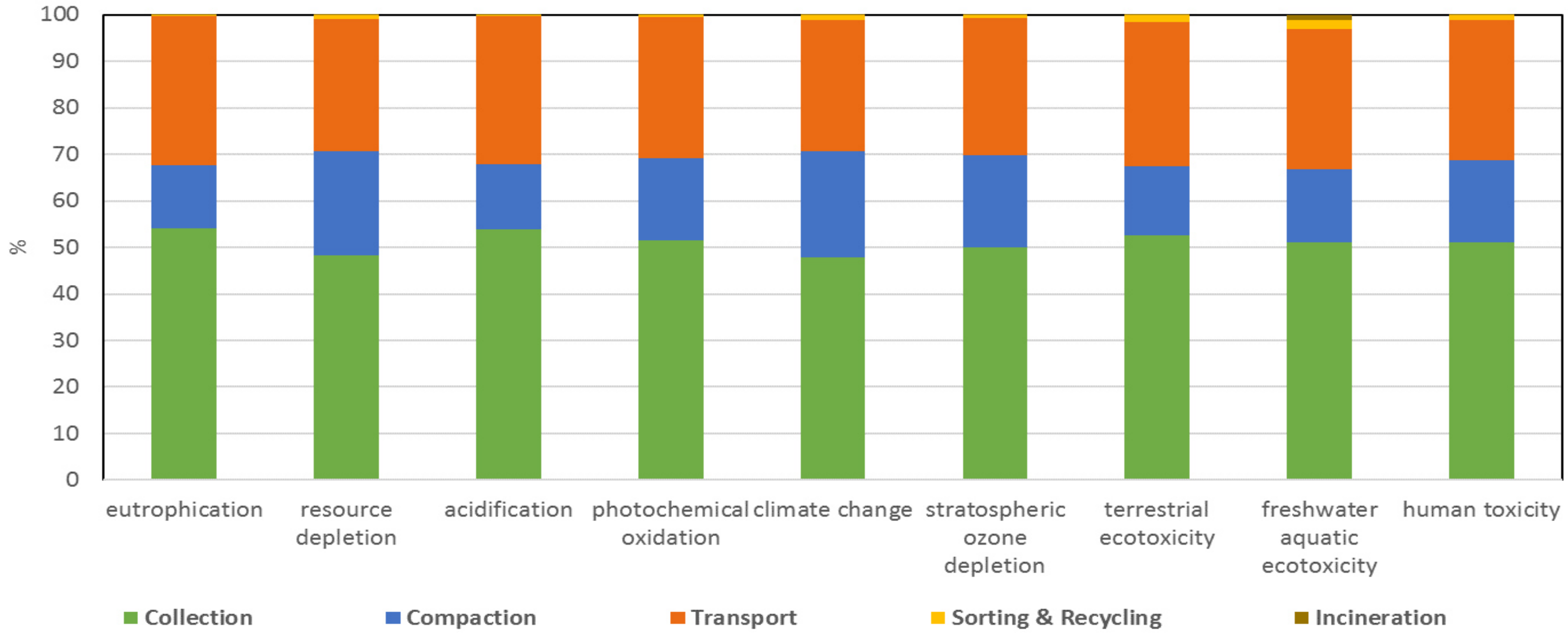
Freshwater ecotoxicity is related to the emissions of heavy metals, like nickel, vanadium, cobalt and beryllium, among others, from the extraction of diesel and from the incineration of plastic losses.

Finally, human toxicity is mainly related to the transport stage and diesel extraction to be used in the stages of collection and compaction. These processes have the potential to emit compounds like benzene, barite, PAH and heavy metals, which are related to impacts on human toxicity.

Table 6-9: Contribution of each stage per impact category for SC3

Impact category	Collection	Compaction	Transport	Sorting &Recycling	Incineration	Total	Unit
eutrophication	1.1E-01	2.8E-02	6.6E-02	6.9E-04	1.5E-05	2.1E-01	kg PO4-eq
resource depletion	7.1E-01	3.3E-01	4.2E-01	1.5E-02	2.1E-05	1.48	Kg antimony-eq
acidification	4.9E-01	1.3E-01	2.9E-01	2.1E-03	3.3E-05	9.1E-01	kg SO2-eq
photochemical oxidation	1.9E-02	6.5E-03	1.1E-02	2.0E-04	1.1E-06	3.7E-02	kg ethylene-eq
climate change	111	52.9	65.6	2.28	0.18	232	kg CO2-eq
stratospheric ozone depletion	1.7E-05	6.6E-06	9.8E-06	2.4E-07	2.7E-10	3.34E-05	kg CFC-11-eq
terrestrial ecotoxicity	1.1E-01	3.1E-02	6.5E-02	3.1E-03	4.2E-05	2.1E-01	kg 1,4-DCB-eq
freshwater aquatic ecotoxicity	3.26	1.00	1.92	0.13	0.07	6.38	kg 1,4-DCB-eq
human toxicity	23.6	8.1	13.9	0.50	0.05	46.2	kg 1,4-DCB-eq

Figure 6-13: Contribution of each stage per impact category for SC3



6.5.3 Sensitivity analysis

In this section, sensitivity analyses on specific parameters is carried out, to evaluate how the results are affected by the chosen allocation method and main assumptions done during the study, and to improve the interpretation of results. The data used to develop the tables and graphs presented in this section is available in Appendix F.

6.5.3.1 *Sensitivity of the selected allocation method*

As observed during the systematic review in chapter 5, the authors of the selected references chose to solve the multifunctionality problem with the substitution method or the "avoided burden" method. None of the selected studies evaluated the effects of the chosen allocation method on the results. As mentioned in the Handbook of Life Cycle Assessment (Guinée et al. 2002), no method to solve the multifunctionality problem of a process can be considered as the best or preferred method. The handbook also mentions the importance of evaluating the sensitivity of the chosen method.

During this case study, multifunctionality problems are solved using economic allocation, as suggested by the Handbook of Life Cycle Assessment (Guinée et al. 2002). In order to evaluate the influence of the selected allocation method, a sensitivity analysis is performed. During this sensitivity analysis, the allocation method is changed to substitution, also known as the "avoided burden" method.

The substitution method implies that the multifunctional unit process under study delivers a byproduct that replaces the production of a product with similar features (Guinée et al. 2002). Thus, during the substitution method, the "avoided impacts" of the "avoided products" are subtracted from the total impacts generated in the system under study. The multifunctional processes of the system under study are "incineration of MPW" in scenario SC2, "sorting and mechanical recycling of MPW" in scenario SC3 and "incineration of unsorted plastics and losses from recycling" in scenario SC3.

The produced byproduct of the incineration of MPW, i.e. electricity from waste, replaces the electricity from the mix, which is a combination of 50% hydropower and 50%

thermos-electricity from natural gas. The assumed replacement ratio is 1:1, which means that 1 kWh of electricity from waste replaces 1 kWh from the electricity mix (0.5 kWh from hydropower and 0.5 kWh from natural gas).

In the case of the process of sorting and mechanical recycling, the produced byproducts, i.e. recycled plastic pellets, are assumed to substitute plastic pellets from virgin materials by a replacement ratio of 1:1. This means that 1 kg of recycled plastic pellets replace 1 kg of plastic pellets from virgin materials.

The details of the substitution are shown in Table 6-10. In Table 6-10, it can be seen how the products (goods) of the incineration process and recycling process replace the production of specific products from virgin materials. These replacements are "avoiding" the burden that in other case would have been emitted to the environment. Thus, to solve the multifunctionality problem of the processes of incineration and sorting and mechanical recycling, the avoided burden is subtracted from the total burden generated in the process.

Table 6-10: Applying substitution to the multifunctional processes of "incineration" and "sorting and mechanical recycling"

Process	Functional flow	Quantity	Assumed avoided process	Quantity
SC2 Incineration of MPW	SC2 electricity from waste	1116 kWh	electricity from natural gas [RER]	558 kWh
			electricity from hydropower [BR]	558 kWh
SC3 Sorting and mechanical recycling of MPW	SC3 PET pellets	216 kg	PET from virgin materials [RER]	216 kg
	SC3 PP pellets	66.8 kg	PP from virgin materials [RER]	66.8 kg
	SC3 PVC pellets	66.8 kg	PVC from virgin materials [RER]	66.8 kg
	SC3 PS pellets	66.8 kg	PS from virgin materials [RER]	66.8 kg
	SC3 HDPE pellets	66.8 kg	HDPE from virgin materials [RER]	66.8 kg
	SC3 LDPE pellets	372 kg	LDPE from virgin materials [RER]	372 kg
SC3 Incineration of losses and unsorted plastics	SC3 electricity from waste	140 kWh	electricity from natural gas [RER]	70 kWh
			electricity from hydropower [BR]	70 kWh

[RER]: location of the process: regional – Europe
[BR]: location of the process: Brazil

In Table 6-11, the characterization results for the three scenarios are shown, using substitution to solve the multifunctional problem. In Figure 6-14, a comparison is shown between the characterization results when economic allocation is used to solve multifunctionality (presented in section 6.4.2) versus the results when the substitution method is used instead. Since the baseline scenario SC1 does not include any multifunctional processes, these results remain the same in both cases.

The characterization results show that the recycling scenario, SC3, has a better environmental performance in all but one impact category. The impacts of the recycling scenario are mostly negative, because of the avoided impacts of not having to produce plastic pellets from virgin materials.

In the case of stratospheric ozone depletion, the scenario SC2 (100% incineration of MPW) appears to be more environmentally favorable than the recycling scenario SC3 (85.5% recycling and 14.5% incineration). This is because the impacts on this category are mainly related to the production of electricity from natural gas, which releases the compound Halon 1211 ($CBrClF_2$). In the case of the incineration scenario SC2, half of the generated electricity from waste avoids the impacts of producing electricity from natural gas, i.e. the emissions of the Halon 1211 (see Table 6-10). This avoided burden makes the scenario SC2 more environmentally favorable than SC3 in this impact category.

The results also show that, if substitution is used instead of economic allocation, the scenario SC2 turns out to be less environmental favorable than the baseline scenario SC1 in six out of nine impact categories. These results are related to the type of electricity avoided in the Peruvian situation. As mentioned before, the electricity mix in Peru is assumed to be 50% hydropower and 50% thermoelectric generation from natural gas. This type of electricity is cleaner than electricity produced from coal or other fossil fuels, and generates less environmental impacts. Thus, the amount of assumed “avoided impacts” of SC2 are not significant and do not offset the generated impacts during incineration of MPW.

These results show that the allocation method chosen to solve the multifunctionality problem is determining and important to evaluate. If partitioning by economic allocation is chosen, the obtained characterisation results show more clearly that the recycling scenario SC3 is environmentally preferable compared to scenarios SC2 and SC1. Also, with economic allocation, the incineration scenario SC2 is preferable compared to the baseline scenario SC1. However, if the “avoided burden” method is chosen instead, the most environmentally preferable scenario is not completely clear, because no scenario is the most environmentally preferable option for all the selected impact categories. Similarly, it cannot be concluded that the incineration scenario SC2 is environmentally preferable to the baseline scenario SC1, or in other words, that incineration of MPW is better than landfilling MPW.

It is important to mention again, that the impacts generated for the disposal of plastics in open dumps and water bodies are underestimated during the calculations because of lack of data specific to this type of disposal.

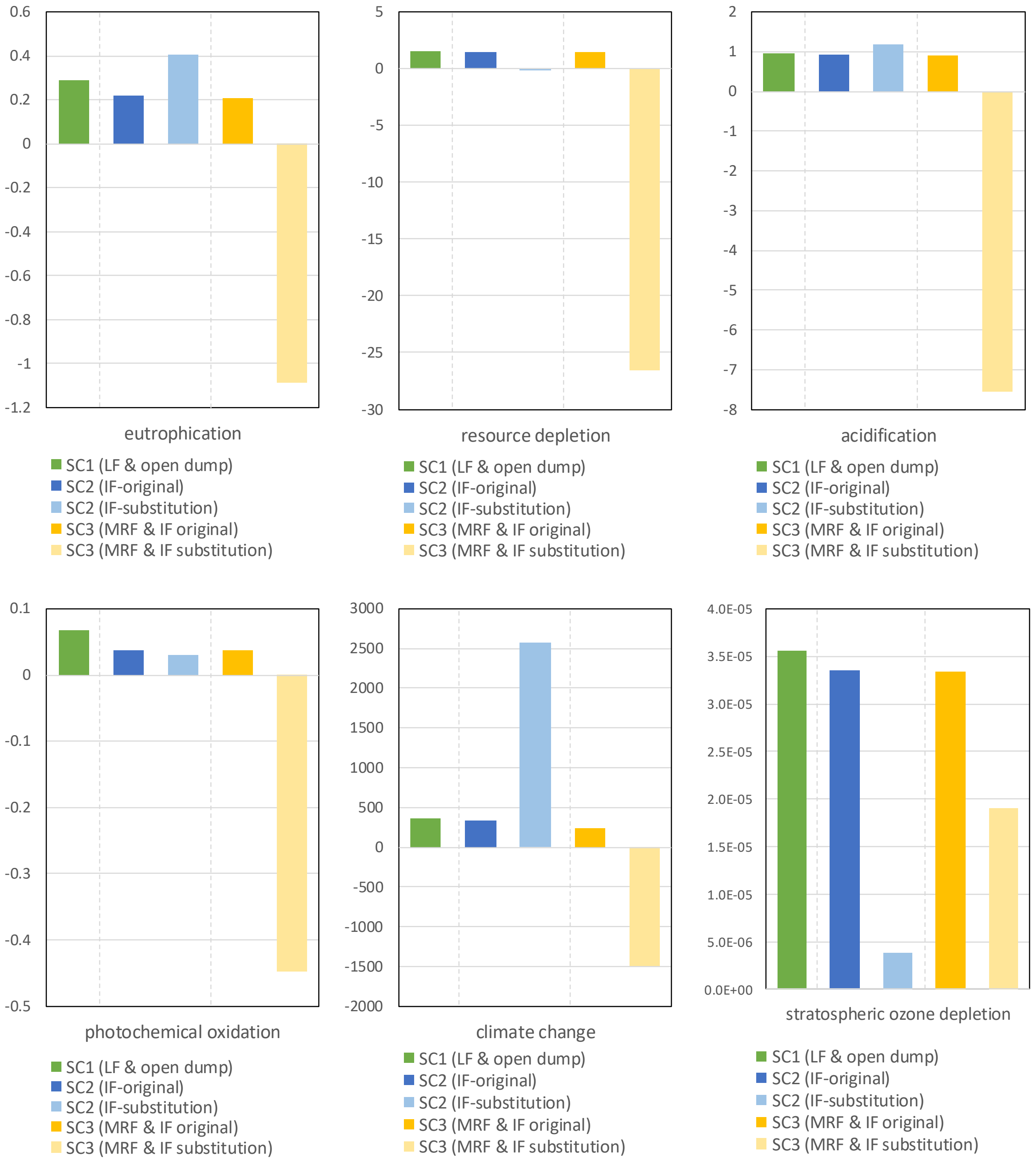
Table 6-11: Characterization results if substitution method is used to solve multifunctionality of the incineration process and the sorting and recycling process

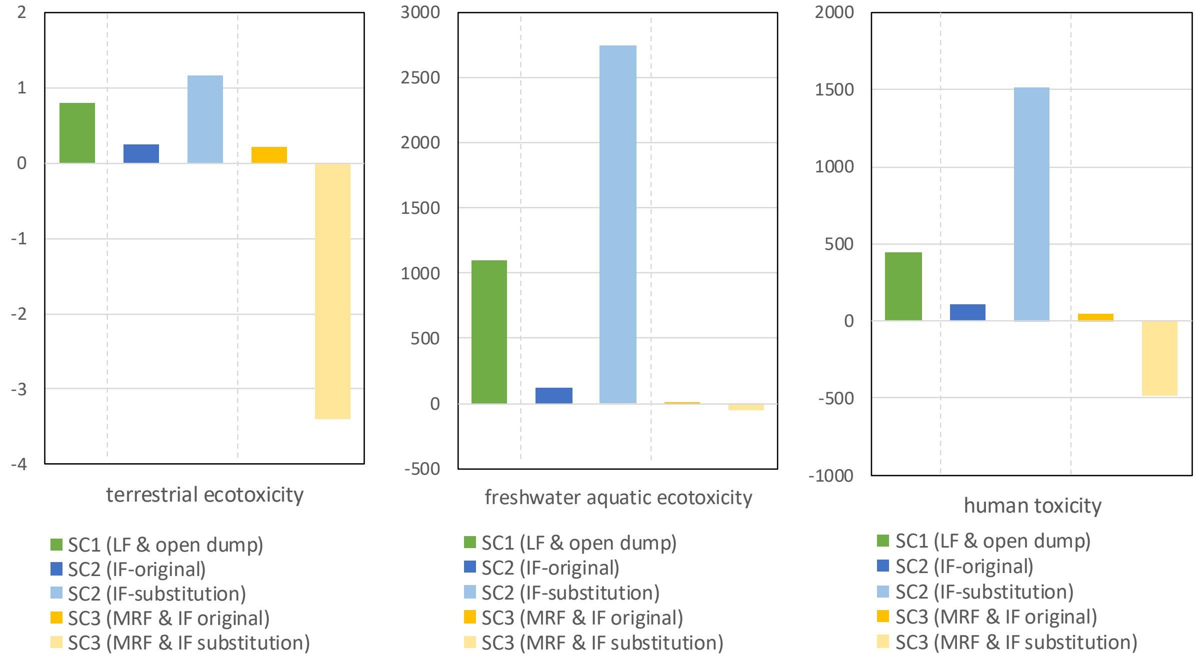
Impact category	SC1 (75% LF & 25% open dump)	SC2 (100% IF)	SC3 (85.5% MRF & 14.5% IF)	Unit
eutrophication	0.292	0.407	-1.085	kg PO4-eq
resource depletion	1.57	-0.13	-26.6	kg antimony-eq
acidification	0.96	1.19	-7.54	kg SO2-eq
photochemical oxidation	0.066	0.031	-0.45	kg ethylene-eq
climate change	365	2574	-1492	kg CO2-eq
stratospheric ozone depletion	3.56E-05	3.90E-06	1.90E-05	kg CFC-11-eq
terrestrial ecotoxicity	0.797	1.1629	-3.40	kg 1,4-DCB-eq
freshwater aquatic ecotoxicity	1100	2747	-53.4	kg 1,4-DCB-eq
human toxicity	441	1517	-485	kg 1,4-DCB-eq

Indicates the higher value from the three scenarios

Indicates the lower value from the three scenarios

Figure 6-14: Characterization results - comparison of the effects of choosing economic allocation vs. avoided burden method for solving multifunctionality problems





6.5.3.2 *Sensitivity of the selected type of electricity mix*

As mentioned above, if we choose the "avoided burden" method to solve multifunctionality problems, the scenario SC2 turns out to be less environmentally favorable than the baseline scenario SC1 in six out of nine selected impact categories. This is because the electricity substituted in scenario SC2 is generated from hydropower (50%) and thermoelectric from natural gas (50%). This is specific for the current situation in Lima, Peru, where the average electricity production comes from hydropower and natural gas, which result in low environmental impacts compared to other sources of electricity production, like hard coal or other fossil fuels.

Nevertheless, the electricity generated in the incineration facility could also replace a different source of electricity from fossil fuels, like coal for example. Thus, it is important to consider the consequences of replacing electricity from hard coal instead of replacing electricity from hydroelectric and thermoelectric power plants.

As observed in Table 6-12, if the electricity replaced by the incineration of MPW is electricity from hard coal, the scenario SC2 becomes more favorable than the baseline scenario in six out of nine impact categories. Still, the amount of "avoided impacts" of SC2 are not significant enough in the categories climate change, freshwater ecotoxicity and human toxicity to offset the generated impacts during incineration of MPW. Also, for the impact categories resource depletion and photochemical oxidation, the scenario SC2 shows better environmental performance than the recycling scenario SC3.

Similarly, the characterization results of scenario SC3 show an even better environmental performance of SC3 compared to the baseline scenario SC1, with smaller negative impacts.

Table 6-12: Characterization results if substitution method is used to solve multifunctionality of incineration process and sorting and recycling process, considering substitution electricity from coal

Impact category	SC1 (75% LF & 25% open dump)	SC2 (100% IF)	SC3 (85.5% MRF & 14.5% IF)	Unit
eutrophication	0.292	-1.961	-1.382	kg PO4-eq
resource depletion	1.57	-7.39	-27.52	kg antimony-eq
acidification	0.964	-11.42	-9.13	kg SO2-eq
photochemical oxidation	0.0664	-0.3934	-0.5004	kg ethylene-eq
climate change	365	1670	-1605	kg CO2-eq
stratospheric ozone depletion	3.56E-05	3.21E-05	2.25E-05	kg CFC-11-eq
terrestrial ecotoxicity	0.797	-1.02	-3.678	kg 1,4-DCB-eq
freshwater aquatic ecotoxicity	1100	2361	-101.9	kg 1,4-DCB-eq
human toxicity	441	1073	-541	kg 1,4-DCB-eq

Indicates the higher value from the three scenarios
Indicates the lower value from the three scenarios

6.5.3.3 *Sensitivity of the selected replacement ratio*

During the systematic review of selected references (section 5) it was pointed out that the assumed substitution ratio of the generated coproducts directly affect the environmental performance of recycling schemes. In the case study, it is assumed that the replacement ratio is 1:1, which means that 1 kg of recycled plastic pellets replace 1 kg of plastic pellets from virgin materials. In order to evaluate the effects of this assumption, a replacement ratio of 1:0.5 is applied.

First, the sensitivity of the replacement ratio is evaluated when economic allocation is chosen as the method to solve the multifunctional problem in the process “sorting and mechanical recycling of MPW”. Second, the sensitivity of the replacement ratio is evaluated when substitution or “avoided burden” method is chosen to solve the multifunctional problem.

When economic allocation is chosen as the method to solve multifunctionality, if a replacement ratio of 1:1 is considered, then the prices of the obtained goods (recycled plastic pellets) are the same as the prices of the goods produced from virgin materials. Table 6-2 shows the economic values of the goods when a replacement ratio of 1:1 is applied. If a replacement ratio of 1:0.5 is considered instead, then it is assumed that the price of the generated goods (recycled plastic pellets) are only valued as half of the price of the same amount of goods from virgin materials. This can be seen in detail in Table 6-13 where the economic value of the goods of recycled pellets is half of the price considered in Table 6-2.

However, even when considering half of the price of the goods from virgin materials, the allocation factors of all the functional flows remain similar as the ones observed when a replacement ratio of 1:1 is considered. This is because the proceeds are mainly related to the obtained secondary plastic pellets.

Table 6-13: Functional flows, economic values and allocation factors when replacement ratio of 1:0.5 is applied for the sorting and mechanical recycling process

Process	Funtional flow	Quantity	Economic value	Unit	Proceeds	Allocation factor
SC3 Sorting and mechanical recycling of MPW	SC3 Separated MPW	-855 kg	-0.0083	USD/kg [a]	7.1	0.02
	SC3 PET pellets	216 kg	0.63	USD/kg [b]	136.1	0.36
	SC3 PP pellets	66.8 kg	0.52	USD/kg [b]	34.7	0.09
	SC3 PS pellets	66.8 kg	0.75	USD/kg [b]	50.1	0.13
	SC3 HDPE pellets	66.8 kg	0.57	USD/kg [b]	38.1	0.10
	SC3 LDPE pellets	372 kg	0.245	USD/kg [b]	91.1	0.24
	SC3 PVC pellets	66.8 kg	0.385	USD/kg [b]	25.7	0.07
				Total proceeds	**382.9**	

[a] Source: MINAM 2009
[b] Source: Plastic News 2017 – Considered half of the original price

Table 6-14 presents the characterization results obtained when applying economic allocation and assuming a replacement ratio of 1:0.5 in scenario SC3 for the sorting and recycling phase. It can be seen here that the results in this case are barely affected by the replacement ratio. This is because the economic allocation assigns most of the impacts to the generated goods, instead of the recycled waste.

Table 6-14: Effects of the replacement ratio of recycled plastics when economic allocation is chosen to solve the multifunctionality problem

Impact category	SC1 (75% LF & 25% open dump)	SC2 (100% IF)	SC3 (1:0.5)	*SC3 (original 1:1)*	Unit
eutrophication	0.292	0.217	0.209	*0.208*	kg PO4-eq
resource depletion	1.57	1.49	1.49	*1.48*	kg antimony-eq
acidification	0.964	0.928	0.911	*0.909*	kg SO2-eq
photochemical oxidation	0.0664	0.0376	0.0371	*0.0369*	kg ethylene-eq
climate change	365	342	234	*232*	kg CO2-eq
stratospheric ozone depletion	3.56E-05	3.35E-05	3.36E-05	*3.34E-05*	kg CFC-11-eq
terrestrial ecotoxicity	0.797	0.252	0.214	*0.211*	kg 1,4-DCB-eq

Impact category	SC1 (75% LF & 25% open dump)	SC2 (100% IF)	SC3 (1:0.5)	*SC3 (original 1:1)*	Unit
freshwater aquatic ecotoxicity	1100	121	6.57	*6.38*	kg 1,4-DCB-eq
human toxicity	441	109	46.7	46.2	kg 1,4-DCB-eq

Indicates the higher value from the three scenarios
Indicates the lower value from the three scenarios

When substitution or the "avoided burden" method is chosen to solve multifunctionality problems and a replacement ratio of 1:1 is considered, then the quantity of the assumed avoided processes is equal to the quantity of the correspondent functional flows. If a replacement ratio of 1:0.5 is assumed instead, then the quantity of assumed avoided processes is equal to half of the quantity obtained in each functional flow. For the process of sorting and mechanical recycling, the amount of avoided processes is shown in detail in Table 6-15.

Table 6-15: Replacement ratio of 1:0.5 applied for the sorting and mechanical recycling process when substitution is used to solve multifunctionality

Process	Functional flow	Quantity	Assumed avoided process	Quantity
SC3 Sorting and mechanical recycling of MPW	SC3 PET pellets	216 kg	PET from virgin materials [RER]	108 kg
	SC3 PP pellets	66.8 kg	PP from virgin materials [RER]	33.4 kg
	SC3 PVC pellets	66.8 kg	PVC from virgin materials [RER]	33.4 kg
	SC3 PS pellets	66.8 kg	PS from virgin materials [RER]	33.4 kg
	SC3 HDPE pellets	66.8 kg	HDPE from virgin materials [RER]	33.4 kg
	SC3 LDPE pellets	372 kg	LDPE from virgin materials [RER]	186 kg

Table 6-16 presents the characterization results obtained when a replacement ratio of 1:0.5 is considered in scenario SC3 for the sorting and recycling phase, when substitution is considered as the method to solve multifunctionality. It can be seen that in this case, the change in substitution ratio clearly affects the characterization results of the recycling scenario SC3. For seven out of nine impact categories, the environmental impacts increase by at least 40% when the substitution ratio is 1:0.5 instead of 1:1.

It can be concluded that the replacement ratio in this case study has a significant influence on the environmental impact results when a substitution method is selected. When economic allocation is chosen instead as a method, the effects on the characterization results are minimal.

Table 6-16: Effects of the replacement ratio of recycled plastics when substitution method is chosen to solve the multifunctionality problem

Impact category	SC1 (75% LF & 25% open dump)	SC2 (100% IF)	SC3 (1:0.5)	*SC3 (original 1:1)*	Unit
eutrophication	0.292	0.4072	-0.393	*-1.09*	kg PO4-eq
resource depletion	1.57	-0.13	-12.01	*-26.61*	kg antimony-eq
acidification	0.96	1.19	-3.20	*-7.54*	kg SO2-eq
photochemical oxidation	0.066	0.031	-0.196	*-0.45*	kg ethylene-eq
climate change	365	2574	-382	*-1492*	kg CO2-eq
stratospheric ozone depletion	3.56E-05	3.90E-06	3.52E-05	*1.90E-05*	kg CFC-11-eq
terrestrial ecotoxicity	0.797	1.163	-1.414	*-3.404*	kg 1,4-DCB-eq
freshwater aquatic ecotoxicity	1100	2747	49.63	*-53.37*	kg 1,4-DCB-eq
human toxicity	441	1517	-150	*-485*	kg 1,4-DCB-eq

Indicates the higher value from the three scenarios
Indicates the lower value from the three scenarios

6.5.3.4 *Sensitivity of the assumed transport distances*

As mentioned before, transport distances for all scenarios are assumed to be 50 km in total, and assumed to be carried out by a 21 tonnes lorry. This assumption is only a guess of the possible distances of transported wastes. As observed in the characterization results and contribution analysis, collection and transport of MPW are big contributors of environmental impacts on all the scenarios. This is especially notable for scenario SC3, where all impact categories are driven by the impacts of collection and transport.

It is important to analyse how sensitive the results are for the recycling scenario SC3 when the transport distances increase. Transport distances could increase if the MPW is taken to a different city outside Lima, for example. In order to analyse the effects of increasing transport distances in the recycling scenario, the initial distance of 50 km is increased by 10 km and 20 km. The characterization results under these changes in scenario SC3, and their comparison with scenarios SC1 and SC2 are presented in Table 6-17.

It can be seen that if transport distances are increased by only 10 km, the recycling scenario SC3 is no longer the preferable option when compared to scenario SC2, for the categories of eutrophication, resource depletion, acidification, photochemical oxidation and stratospheric ozone depletion. Also, in the case of acidification, if the distance is increased by 10 km, scenario SC1 becomes more competitive. If the distance is increased by 20 km instead, the scenario SC3 becomes less favourable than the baseline scenario SC1 for the categories of resource depletion, acidification and stratospheric ozone depletion too.

These results tell us that the transport stage is an important contributor of the environmental impacts, especially of the non-toxic impact categories. Variations on the transport distances directly affect the performance of the scenarios in general. Thus, it is important to take into consideration the influence of transport in the overall impacts of the scenarios and propose better and more efficient collection and transport systems in the country.

Table 6-17: Sensitivity of characterization results of recycling scenario SC3 when transport distances are increased by 10 km and 20 km

Impact category	SC1 (75% LF 25% open dump)	SC2 (100% IF)	SC3 (85.5% MRF & 14.5% IF)	SC3 +10km	SC3 +20km
eutrophication	0.292	0.217	0.208	**0.221**	**0.235**
resource depletion	1.57	1.49	1.48	**1.56**	***1.64***
acidification	0.964	0.928	0.909	***0.967***	***1.02***
photochemical oxidation	0.0664	0.0376	0.0369	**0.0391**	**0.0414**
climate change	365	342	232	245	258
stratospheric ozone depletion	3.56E-05	3.35E-05	3.34E-05	**3.53E-05**	***3.73E-05***

Impact category	SC1 (75% LF 25% open dump)	SC2 (100% IF)	SC3 (85.5% MRF & 14.5% IF)	SC3 +10km	SC3 +20km
terrestrial ecotoxicity	0.797	0.252	0.211	0.224	0.237
freshwater aquatic ecotoxicity	1100	121	6.38	6.77	7.15
human toxicity	441	109	46.2	49	51.8

BOLD: SC3 with larger impacts than SC2
ITALIC: SC3 with larger impacts than SC1

6.5.3.5 *Sensitivity of emissions from landfills in the long-term vs short-term*

To model the process of landfill, the Ecoinvent process "disposal, plastics, mixture, 15.3% water, to sanitary landfill" is used as a base. This process includes all the potential emissions in the short- and long-term, and treats them all as short-term emissions. Thus, it is important to perform a sensitivity analysis to evaluate the influence of these long-term emissions in the final results.

Plastics in general have a slow degradation rate in the environment. When disposed in landfills, it is assumed that only 1% of the amount will degrade in the short-term, during the first 100 years (Doka 2009). The long-term is assumed to be from 100 years till 60'000 years. During this period, the entire amount of MPW will decompose and generate leachate.

To evaluate the effects of each timescale into the final results of the baseline scenario SC1, the impacts on the short-term and long-term are separated and compared to the final results. To do this, the Ecoinvent Excel file "13_MSWLFv2.xls" was modified. The Excel file shows the calculations of the short- and long-term periods separately, to sum them up at the end to create the total impact of the process of sanitary landfill. One way of analyze the impacts of both terms separately is to extract the impacts only for the short term from the excel file, by assuming zero impacts on the long term. Then, by subtracting the impacts of the short-term from the total impacts of sanitary landfill, the impacts of the long-term period are calculated. The process of how to modify these files is available in Appendix D.

Table 6-18 shows the impact of the disposal of 75% of the MPW into a sanitary landfill, as part of the scenario SC1. It also shows the contribution from the short-term and long-term emissions to this total impact. The impacts attributable to the long-term emissions are highly important for the categories of terrestrial, freshwater and human toxicity. In these categories between 94% and 100% of the total impacts come from long-term emissions. It is important to point out that these impacts also represent between 69% and 99% of the total impact of scenario SC1, and thus when conclusions are drawn these results should be treated carefully.

Similarly, it can be observed that the short-term emissions are 100% accountable to the impacts of resource depletion, acidification and stratospheric ozone depletion. Also, in these three categories, the total impacts (short- and long-term) of the process alone of sanitary landfill represent around 20% of the total impacts on scenario SC1.

Table 6-18: Contribution from the short-term and long-term emissions to the total impact of sanitary landfill in SC1

Impact category	Total impact of sanitary landfill (75% of MPW in SC1)	Contribution from short-term	Contribution from long-term
eutrophication	0.0841	65%	35%
resource depletion	0.102	100%	0%
acidification	0.0558	100%	0%
photochemical oxidation	0.0227	57%	43%
climate change	103	65%	35%
stratospheric ozone depletion	2.33E-06	100%	0%
terrestrial ecotoxicity	0.587	6%	94%
freshwater aquatic ecotoxicity	1090	0%	100%
human toxicity	394	2%	98%

6.5.3.6 *Sensitivity of untreated emissions from landfills in Peru*

As mentioned during the description of the baseline scenario SC1, for this case study it is assumed that all landfill gases (LFG) generated in the sanitary landfills are emitted to the atmosphere without previous treatment. In order to evaluate the effects of this assumption in the final results, the percentage of captured LFG is changed.

The Ecoinvent process “disposal, plastics, mixture, 15.3% water, to sanitary landfill” assumes that 53% of the generated gases in the landfill are directly emitted and 47% can be recovered and burned (Doka 2009a). Following this assumption, the impacts of disposing 75% of MPW in a sanitary landfill with 47% of LFG capture is evaluated.

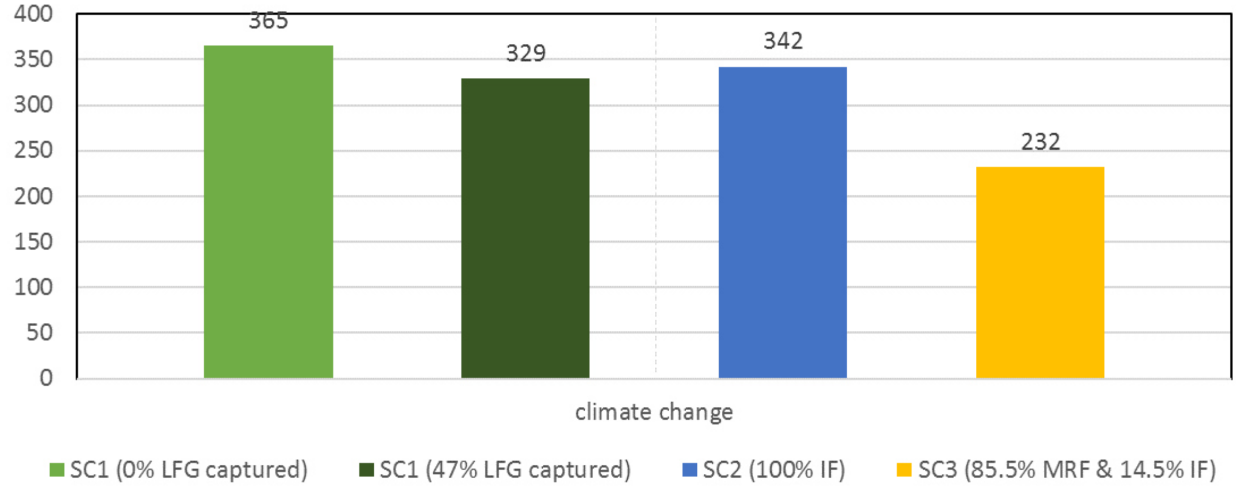
Table 6-19 shows that the only differences between the impacts of a sanitary landfill with 0% of LFG capture (case study) and one with 47% of LFG capture are observed for the categories of photochemical oxidation and climate change. Assuming 47% of LFG captured reduces the impacts of photochemical oxidation by 43% and of climate change by 35%.

Table 6-19: Effects of different amounts of LFG capture in sanitary landfills

Impact category	75% of MPW in landfill with 0% LFG captured	75% of MPW in landfill with 47% LFG captured
eutrophication	0.0841	0.0841
resource depletion	0.102	0.102
acidification	0.0558	0.0558
photochemical oxidation	**0.0227**	**0.013**
climate change	**103**	**67.3**
stratospheric ozone depletion	2.33E-06	2.33E-06
terrestrial ecotoxicity	0.587	0.587
freshwater aquatic ecotoxicity	1090	1090
human toxicity	394	394

These reductions are also significant for the total impacts of the baseline scenario SC1. The reduction on photochemical oxidation by capturing 47% of the LFG represents a reduction of 15% of the total impact of SC1. Also, the reduction on climate change, represents a reduction of 10% of the total impact of SC1. In the case of climate change, this reduction makes the baseline scenario SC1 (with 329 kg CO_2-eq) more environmentally preferable in comparison to the incineration scenario SC2 (with 342 kg CO_2-eq), as observed in Figure 6-15. Thus, the characterization results for climate change of SC1 are sensitive to the assumption of the amount of LFG that is captured and burnt in sanitary landfills, but the differences remain small.

Figure 6-15: Comparison of climate change impacts on SC1 with 0% LFG capture and 47% LFG capture, vs SC2 and SC3



6.5.3.7 *Sensitivity of untreated emissions from open dumps in Peru*

As mentioned in section 6.3.2, in this case study the environmental impacts of disposing MPW in open dumps are estimated based on the untreated emissions (LFG and leachate) from a sanitary landfill during the short-term (100 years). This is only a rough estimation, since the real impacts of disposing MPW in open dumps, water bodies and the ocean are greater and dependent on the environmental conditions of each area.

Still, it is important to evaluate what percentage of the total impacts of the baseline scenario SC1 belongs to the estimated impacts of open dumps, since these impacts are just a rough estimation. To do this, the impacts of disposing 25% of the MPW in open dumps are calculated separately and shown in Table 6-20. In this table, we can observe that the estimated impacts of disposing MPW in open dumps are relevant only for the categories of photochemical oxidation and climate change. For these two categories, the impacts of open dumps represent 10.4% for photochemical oxidation and 8.6% for climate change of the total impacts accounted for the scenario SC1.

For all the other impact categories, the estimated impacts of using open dumps represent less than 1% of the total impacts of scenario SC1. However, there is a lack of real data related to the potential impacts of disposing MPW in open dumps, which makes the calculated impacts an underestimation of the potential real ones (see discussion in section 7).

Table 6-20: Estimated impacts of disposing 25% of MPW in open dumps and its comparison to the total impacts of baseline scenario SC1

Impact category	25% of MPW in open dumps	SC1 total (75% LF & 25% open dump)	% impacts from open dump in SC1
eutrophication	0.00006	0.292	0.02%
resource depletion	-	1.57	0%
acidification	0.0006	0.964	0.06%
photochemical oxidation	0.007	0.0664	**10.4%**
climate change	31.2	365	**8.6%**
stratospheric ozone depletion	-	3.56E-05	0%
terrestrial ecotoxicity	0.002	0.797	0.22%
freshwater aquatic ecotoxicity	0.91	1100	0.08%
human toxicity	0.72	441	0.16%

7. Discussion

The goal of this research is to evaluate the environmental implications of different MPW management options for the city of Lima, Peru, and identify the option with the better environmental performance. To achieve this goal, the study was divided in two stages. First, an inventory and systematic review of existing LCAs of MPW and/or MSW management was performed. This first stage gave the study useful data, lessons learned and main conclusions of similar evaluations performed.

The second stage of the study was the development of an LCA of MPW management in Lima, Peru, using the data retrieved from the first stage, lessons learned and specific data collected of the Peruvian situation. This stage aimed to identify which option of MPW management is more environmentally viable and under which circumstances, while evaluating the potential negative impacts of landfill and open dumps.

7.1 Lessons from the systematic review and their application to the case study

The systematic review of the selected studies gave a comprehensive overview of the current available LCA studies of MPW management. The review showed the importance of transparency during reporting and necessity of more clarification during the description of the economic system under study. Also, the review showed that all the case studies used substitution method to solve the multifunctional problem, and did not discuss the effects of this choice in the final results.

During the case study, the aim was to produce a transparent report in relation to the data used, the assumptions considered, the cut-offs of processes and the effects of decisions taken during the development of the study. A detailed goal and scope definition were performed, followed by a description of the boundaries of the system under study, the cut-offs applied and how multifunctionality problems were solved. Also, the effects of the main assumptions taken during the study were evaluated in order to see the robustness of the final results.

Comparing different ways to solve multifunctionality

In relation to multifunctionality, the evaluated studies during the literature review showed that all of them chose to solve the multifunctionality problem by applying substitution method. None of the studies mentioned or evaluated the effects on the results of choosing other ways to solve multifunctionality. On the other hand, the majority of the studies acknowledged in their conclusions that the biggest contributor to the reduction of impacts was the subtracted impact from the avoided processes due to recycling and incineration.

During the case study, the economic allocation method was chosen to solve the multifunctionality problem, as suggested by the Dutch Handbook on LCA (Guinée et al. 2002). Since all of the selected studies applied substitution as the method to solve multifunctionality, this method was also applied as a sensitivity analysis to evaluate the effects of both methods on the final results of the three case study scenarios.

The results appeared to depend heavily on the selected allocation method. In the case of economic allocation, the characterization results were all represented by positive numbers. Negative numbers are not possible since the method to solve the multifunctionality problem is based on the partitioning of the impacts among the functional flows. When economic allocation is applied, the prices of the wastes and goods play an important role as together with the size of these functional flows, they constitute the basis for the partitioning of the impacts among the functional flows. Since the prices of recycled plastics and generated electricity during incineration are much higher than the costs charged for waste handling, most of the impacts are allocated to the recycled plastics and generated electricity.

When substitution was performed instead of economic allocation to solve multifunctionality, most of the environmental impacts for the selected categories for the recycling scenario SC3 were represented by negative numbers. This is related to the fact that when substitution is applied, the multifunctional problem is solved by the subtraction of the avoided burdens of replaced products. These results are similar to the ones observed in the evaluated case studies. In these studies, the substitution method was used and negative numbers arose especially for the recycling scenarios.

The results of applying economic allocation showed that the best option for all the impact categories is the recycling scenario SC3, followed by the incineration scenario SC2, under all the assumptions considered for the case study. These results agreed with the systematic review, which showed that for climate change the selected studies also identified their recycling scenarios as the environmentally best options.

When the substitution method was chosen to solve multifunctionality, results were not that clear for all the impact categories. In the case of the recycling scenario SC3, this option appeared as the most environmentally friendly for eight out of nine categories. For the category of stratospheric ozone depletion, the scenario SC2 appeared to be the environmentally better option, which is different from what was observed when economic allocation was applied.

The incineration scenario SC2 was mostly affected when substitution is chosen instead of economic allocation to solve multifunctionality. The incineration scenario SC2 became less environmentally preferable for acidification, eutrophication, climate change, terrestrial ecotoxicity, freshwater ecotoxicity and human toxicity, compared to the baseline scenario SC1. This was because the avoidance of generated electricity does not offset the environmental impacts of incinerating MPW.

These results are more in line with the ones observed during the systematic review, in relation to the negative numbers for the recycling scenario. Only one study, Shonfield (2008), evaluated separately the scenarios of landfill and incineration with energy recovery. This study concluded that for almost all the impact categories the landfill scenario was the least preferable, with exception of climate change, where the incineration scenario showed a larger impact. Also, Shonfield (2008) mentioned that the incineration scenario was the second least preferred scenario, with the exception of stratospheric ozone depletion, where incineration had a better environmental performance compared to the mechanical recycling scenarios.

Type of electricity mix assumed to be substituted or avoided

In the incineration scenario SC2, when substitution method was applied, the generated electricity from waste replaced the electricity mix in Peru. This electricity was assumed to be 50% hydropower and 50% thermoelectric generation from natural gas. This type of electricity is relatively clean if compared to electricity from other fossil fuel sources, like hard coal.

In order to define how the results for SC2 depend on the type of electricity assumed to be substituted or avoided when the substitution method is applied, another sensitivity analysis was carried out. The potential electricity substituted was changed from hydropower-thermoelectric to electricity from hard coal. The sensitivity analysis showed that the results are indeed affected by the type of electricity considered. When electricity from coal was assumed to be substituted by the electricity generated during the incineration of MPW, scenario SC2 showed a better environmental performance compared to the original results when the substituted electricity mix was assumed to be hydropower-thermoelectric.

If electricity from coal was assumed to be substituted, then scenario SC2 became more environmentally preferable to recycling scenario SC3 for eutrophication and acidification. Also, when compared to the baseline scenario SC1, scenario SC2 became more environmentally preferable for six out of nine impact categories, but was still less favourable than scenario SC1 for climate change, freshwater ecotoxicity and human toxicity.

Replacement rates

The material replacement ratio is another important parameter highlighted in most of the selected studies. This parameter shows the amount of virgin material that could be replaced by recycled material and it is related to the quality of the recycled sub-product.

In the developed case study, the replacement ratio was assumed to be 1:1, which means that one kilogram of recycled plastic pellets could replace one kilogram of plastic pellets from virgin materials. To evaluate the effects of this assumption in the final results, a sensitivity analysis was carried out. In this analysis, a replacement ratio of 1:0.5 was evaluated for the scenario SC3, where plastics from virgin materials are replaced by recycling plastics. The sensitivity analysis evaluated the effects of the replacement ratio when the multifunctional problem was solved by economic allocation and when it was solved by substitution instead.

When economic allocation was chosen, a change on the replacement ratio of 50% (1:0.5) was applied by reducing the prices of the obtained recycled goods by half. The final results were barely affected by a change in the substitution ratio. This is mainly because of the difference in prices between the goods and the wastes. Even if the price of the goods was reduced by half, the allocation factors of all the functional flows remained similar as the ones observed when a replacement ratio of 1:1 was considered.

When substitution or the "avoided burden" method was applied instead of economic allocation, if a replacement ratio of 1:0.5 was considered, the amount of avoided virgin plastics was reduced by 50%. In this case, a significant change in the final results was observed. The positive environmental impacts assigned to mechanical recycling were reduced in six impact categories by around 40%. This is because when substitution method is used, a lower replacement ratio reduces directly the avoided burden that is subtracted from the impacts generated in the scenario. Still, even with this reduction of 40%, the recycling scenario remained the better option for eight out of nine impact categories, except for the case of stratospheric ozone depletion.

Data collection

During the systematic review, transparency issues and low data availability were observed in the evaluated LCA reports. This represents a big problem when trying to evaluate different LCA studies altogether, and when trying to obtain data from these reports. The main problems observed were the lack of transparency on how data was obtained and the lack of completeness of data used in the studies in all the economic processes.

For the case study, the transparency of the data collection was increased by detailing the selected data and additional data used. Data for the processes of collection, compaction, transfer, sorting and mechanical recycling was retrieved from the evaluated case studies. Data for the other processes of transport, incineration and landfilling, and data gaps, were filled up using the Ecoinvent database. The data collected was adapted to the Peruvian situation when possible by changing the type of electricity mix used, and the amount and types of plastic fractions available in the MPW in Lima.

All data used in the selected economic processes in the system under study is detailed as transparently as possible in Appendix B. Also, the description of how Ecoinvent processes were modified to adapt them to the Peruvian reality, for the case of landfill and open dump modelling, are described in Appendix A.

It is important to mention that the use of data from previous studies in combination with Ecoinvent database brings data inconsistencies and affects the final results. This is because the data from previous studies is often affected by specific system boundaries and assumptions, that are not possible to avoid. However, since there is a lack of available data specific for Peru, the use of existing data from other studies and the combination with Ecoinvent database makes it possible to evaluate management options of MPW in Lima. This study, even if it is not directly using primary data collected in Lima, gives valuable insights in relation to the impacts of possible alternative management options and the current situation. Also, the study helps to identify hotspots in the defined scenarios that are important impact contributors to the whole system.

Impact categories

The studies evaluated during the literature review included only between one to four impact categories, except for Rigamonti et al. (20140) and Shonfield (2008), who included seven impact categories. According to ISO 14044 (2006), studies intended to be disclosed to the public and including comparative evaluations, should select a "sufficiently comprehensive set of category indicators". Thus, the case study developed in this thesis included a more extensive list of impact categories, following the suggestions of the Dutch Handbook on LCA (Guinée et al. 2002).

Including more impact categories makes the study more complete but also more complex. In this case study, including nine impact categories gives a clearer view of the type of impacts on the environment that each management technique would bring. However, the more impact categories you chose, the more difficult it becomes to choose one scenario with the best environmental performance. To bring final conclusions, it is important to point out under which circumstances one scenario is better than the other one, considering the different potential impacts and the assumptions made during the study.

Transport distances

Transport distances of the MPW from the collection point to the sanitary landfill, municipal incinerator or recycling facility were assumed to be 50 km in all three scenarios. This is only a rough estimation of the possible real distances travelled. Therefore, it is important to evaluate how sensitive the characterization results are for this assumption. To do this, the distances in the recycling scenario SC3 were increased by 10 km and 20 km, and the results were compared to the original results in scenarios SC1 and SC2. This sensitivity analysis was carried out considering economic allocation as the method to solve the multifunctional problem.

The evaluation revealed that the results in the recycling scenario are highly sensitive to increases of the transport distances. If there was an increase of 10 km in distance, the recycling scenario SC3 was no longer the preferable option when compared to the incineration scenario SC2 in five impact categories. The distance increase affects the climate change category but not enough to make the preference shift from SC3 to SC2. The same occurs in the toxic categories, where the difference between the impacts of SC1 and SC2 are too big to be affected with an increase of 10 km. Thus, the effects of increasing the transport distance made the preference shift from SC3 to SC2 or SC1 when the differences in characterization results between the alternatives were not that big.

Variations of the transport distances affect directly the performance of the scenarios in general. Thus, it is important to take into consideration the influence of transport in the overall impacts of the scenarios and propose a better and more efficient collection and transport systems for MSW in the country.

Another important reflection upon the collection and transport stages, is their significant contribution to the total impacts in the three scenarios. During the systematic review, the impacts of the collection and transport stage in the selected studies were mentioned to not be significant or negligible. However, the results of the case study showed that the impacts of the collection and transport stages accounted for around 50% in most of the impact categories in the three scenarios.

One possible explanation of these different conclusions between the reviewed studies and the case study is how the impacts of these stages were quantified. In the case study, the collection and transport stages were modelled using the Ecoinvent process "transport, municipal waste collection, lorry 21t[CH]". This process includes the emissions from the diesel used during transport, the impacts of vehicle use and the impacts of road use.

Most of the evaluated studies did not include data related to the collection and transport process, which makes it difficult to evaluate why the impacts of these stages were so low compared to the case study. Some studies mentioned the amount of diesel used during transport, but did not mention if the accounted impacts considered the emissions as a result of the burning of that diesel, or if the impacts considered the use of a truck. Only two studies mentioned that the emissions were calculated according to the amount of the diesel used, considering distances and truck use. Still, these studies also concluded that the impacts of transport were low compared to other stages.

Sanitary landfills

During the systematic review, it was observed that four studies evaluated a landfill scenario separately. The other studies included landfill as an additional process for final disposal of residues from the management alternatives. Only three studies mentioned the inclusion of a landfill gas (LFG) collection system, and two of these three studies mentioned the percentage of LFG collected. None of the studies evaluated or included a discussion about the effects of a LFG collection system or about the assumption of the amount of LFG collected and flared.

In the case study, it was assumed for the disposal of MPW in sanitary landfills that none of the LFG were collected and treated, and 100% of all LFG generated were released to the environment. This is a good approximation of the reality of sanitary landfills in Lima, where in three out of four landfills, no LFG collection is performed, and only one landfill has a system of gas collection only for a small percentage of generated LFG. Even if the LFG collected in that landfill alone was significant, it is difficult to estimate the actual amount of LFG collected and treated.

It is important to evaluate the sensitivity of the results to the assumption of 0% LFG collection. To do this, the original Ecoinvent process "disposal, plastics, mixture, 15.3% water, to sanitary landfill" was used. This process assumes that 47% of generated LFG are recovered and burned, which is the common situation for sanitary landfills in Switzerland.

The results of scenario SC1 under this assumption only affected the impact categories of photochemical oxidation and climate change, reducing the potential impacts by 15% and 10%, respectively. In the case of photochemical oxidation, this change did not affect the main results, determining the baseline scenario still as the worst scenario. However, in the case of climate change, this change made the baseline scenario in this category a better option when compared to the incineration scenario SC2.

These results stress the importance of LFG collection systems in sanitary landfills, especially in terms of reducing GHG emissions to the environment. Collecting less than half of the landfill gases and burning them could reduce the GHG emissions by 10%, only considering emissions from MPW, which are not as high as for other waste fractions, like organic waste. Therefore, decision makers should not only eliminate the use of open dumps, but also improve the existing sanitary landfills by implementing these gas collection systems.

Another important remark of the calculation of impacts of sanitary landfills is the assumption related to the short- and long-term periods. Considering that plastics have a slow degradation rate, calculating the impacts for the first 100 years (short-term) would mean an underestimation of the real impacts. Ecoinvent in its process of "disposal, plastics, mixture, 15.3% water, to sanitary landfill" assumes also a long-term period from 100 years till 60'000 years, where the majority of the MPW is degraded, generating emissions to the environment.

Calculating emissions for a long-term period of 60'000 years brings uncertainties to the estimated impacts. Thus, the results from this long-term period should be treated cautiously and the contribution to the total impacts should be evaluated. When both periods were separated and their contributions to the total impacts of SC1 were evaluated, it could be seen that the long-term period was for almost 100% responsible of the total impacts of freshwater ecotoxicity, for almost 90% of human toxicity and for almost 70% of terrestrial ecotoxicity.

These toxicity impact categories also have big uncertainties on their own, compared to the rest of non-toxic categories, because the characterization of these impact categories is still partially incomplete and under development. Thus, the characterization results regarding these categories are very uncertain. The characterization results for the toxicity related impact categories showed much higher values for the baseline scenario SC1 compared to scenarios SC2 and SC3. These higher values are related mainly to the impacts calculated for the long-term period.

Open dumps

The environmental evaluation of open dumps in this case study was carried out by representing the potential impacts with the non-treated leachate emissions and LFG emissions of a sanitary landfill. This is only a rough estimation of the potential real impacts of MPW disposed in open dumps, water bodies or the ocean. This estimation in scenario SC1 for 25% of the disposed MPW is only relevant to the categories of photochemical oxidation and climate change. In these two categories, the estimated impacts of open dumps represented 10.4% and 8.6%, respectively. For the other impact categories, the estimated impacts represented less than 1%.

It is important to highlight that, even though disposal of MPW in open dumps was analysed as part of the baseline scenario SC1, this practice should be avoided by all means. Open dumps lack any sanitary control, leachate collection or treatment, bottom protection to avoid infiltrations, or any other needed infrastructure (Doka 2009b; Abarca Guerrero et al. 2013). In these areas, waste scavengers, often children and low-income inhabitants, can be found picking up recyclable materials, to sell them later in exchange of small revenues. These waste pickers work in these areas without any type of personal protective equipment, risking their safety and health.

As mentioned by several authors, disposal of solid waste in open dumps has an enormous impact on the environment and on society, including the increase of soil degradation, flooding risks, pollution of water bodies and air, hygienic risks and direct exposure to pathogens and other hazardous substances to surrounding inhabitants, among others (Ezeah et al. 2013; Laurent et al. 2014a). All these environmental and social impacts have not been considered in this LCA because of lack of data, which means that the actual impacts of disposing MPW in open dumps are being underestimated in this study. However, these impacts are visible to the Peruvian community and are a reality for the country. Any efforts to improve the MPW management of the country must also aim at eliminating the use of open dumps as disposal spaces.

7.2 Approach of the study and its utility

This study started with a systematic review of existing LCA studies of MSW and / or MPW management. This review was performed to obtain useful data that could be employed during the elaboration of the LCA study for Lima, Peru. The review was also used to determine key parameters that are relevant when LCA studies of waste management are performed.

The systematic review revealed that the parameters that seem to be the more crucial and influential in the final results during LCA of waste management are the method chosen to solve multifunctionality problems, the type of electricity mix assumed to be substituted and the assumed replacement ratio of recycled materials. It is important to mention that all studies reviewed used the substitution method to solve multifunctionality, without evaluating the sensitivity of the results of this method compared to other methods to solve multifunctionality.

The approach of starting the study with a systematic review allowed a better understanding of the more important parameters when LCA of waste management is conducted. Also, the review allowed the identification of those aspects that were missing in most of the studies: more transparency during reporting, sensitivity analysis of important modelling choses (i.e. chosen allocation method), clear identification of the inclusions and exclusions in the system under study, among others. Thus, starting a study with a systematic review of existing studies, especially when there is lack of local and reliable data to be used to perform the LCA, is a useful approach and gives more understanding of how to guide the assessment to obtain more reliable results.

7.3 Use of the results

LCA is a method considered suitable for evaluating the environmental implications of waste management options. LCA is an assessment tool, able to analyse relevant environmental impacts of the disposal, incineration or recycling of solid waste (Guinée and Heijungs 2005).

The case study showed that the results depended on modelling decisions and the main assumptions made during the study. The baseline characterization results, under all the assumptions made and using economic allocation, showed first that the recycling scenario was more environmentally preferable to the incineration and the baseline scenario. However, the evaluation of the sensitivity of these results to the allocation method, type of electricity mix assumed, replacement ratio assumed and transport distances showed that the results are subject to change when assumptions are modified and that the permanence of the recycling scenario as the best option is not maintained for all the impact categories.

From the sensitivity analyses, it can be concluded that even though the recycling scenario did not remain as the most preferable option for all the impact categories, it remained for most of them. However, during the evaluation of the sensitivity of the results to the transport distance assumed, it was observed that the results for the recycling scenario changed considerably, making the incineration scenario more favourable in five out of nine categories.

These results show that it is important to improve not only the way MPW is disposed, but also the way it is collected and transported. More efficient systems of collection and transport that could reduce the distances travelled would mean a reduction of the impacts on the environment. Improvement of the collection and transport systems should be part of the main decisions taken by the authorities in Peru.

Also, in this case study, it was assumed that all the landfill gases (LFG) generated in the sanitary landfills were released to the atmosphere without any treatment. The sensitivity of the results to this assumption was evaluated by increasing the amount of collected and incinerated LFG in the sanitary landfills from 0% to 47%. This increase in the LFG collection generated a reduction of the impacts of photochemical oxidation and climate change by 15% and 10%, respectively. These reductions in the mentioned impacts are an important point to be considered by the Peruvian authorities and decision makers. Seeing these environmental benefits, existing landfills in Peru should be implemented with LFG collection systems to contribute to the reductions of impacts on climate change and photochemical oxidation.

This study also revealed the importance of local markets to absorb the generated recycled materials. Thus, the importance of creating more incentives and subsidies to promote and increase the acceptance of recycled materials is highlighted. A successful adaptation of the market to a MPW recycling scheme needs more incentives and subsidies from the government to increase the acceptance and use of recycled materials.

The interpretation of the results and main conclusions obtained in this study should be communicated to the Peruvian community in order to increase awareness of the benefits that mechanical recycling brings to the environment. The Peruvian environmental ministry is currently developing the NAMA program (Nationally Appropriate Mitigation Action) for solid waste. One of the objectives of this program is to calculate the greenhouse gas emissions of MSW in the country and the assessment of mitigation options, among others. This study generates important inputs for the development of that objective.

7.4 Limitations of the LCA study

The present case study has limitations and uncertainties that are mainly related to data gaps, technical limits and assumptions done during the modelling of the system. The collected data used in this system mainly comes from developed countries. There are big difficulties in obtaining precise data from third world countries, including Peru. Thus, the case study does not fully reflect the local characteristics of the country.

Data retrieved from Ecoinvent v2.2 (2010), used to simulate economic processes, has aggregated data of materials and energy that was not possible to adapt to the Peruvian reality. These processes consider technologies, efficiencies, electricity mix, and other components that are closer to the European reality than to a developing country reality. The adaptation of this background data, to resemble current efficiencies, distances or different technologies in Peru, is not part of the scope of the study. Hence, the characterization results of the study could be underestimated in some cases.

Another assumption in this study is the composition of the MPW in Lima. As mentioned before, the platform SIGERSOL was used to retrieve the composition of plastic waste in Lima. However, this platform only separates the MPW in three fractions, PET plastics, plastic bags and hard plastics, but does not specify the polymer types in each group. In this study, it was assumed that all plastic bags were LDPE plastics, and that hard plastics were composed by HDPE, PS, PP and PVC in equal parts. This is only an assumption to facilitate the analysis during the incineration and recycling scenarios. If more detailed information is available in the future, it is suggested to refine the case study by including more precise information about the plastic fractions.

LCA is an environmental assessment method. Therefore, this method does not cover economic and social aspects related to the proposed management alternatives. Also, it does not cover some specific environmental aspects such as impacts associated with the location of a new recycling plant (Ekvall et al. 2007). Additional studies on the implications of the best management alternative must be developed in the future, in order to complement the results and conclusions of this study.

Additional limitations are the different uncertainties that were found in the analysis. Some of these uncertainties are the chosen technologies, the assumed avoided products during incineration and recycling, the energy consumption of processes, and the assumed transport distances.

8. Conclusions and recommendations

8.1 Conclusions

The aim of this study was to evaluate potential solutions for MPW management in Lima, Peru. Considering this aim, the following main research question was developed: **Based on existing LCAs of MPW and MSW management, and focused on the Peruvian context, what is the environmentally best waste management strategy for Lima (Peru) as an alternative to the current practice of open dumps and landfills?** To answer this main research questions, four sub-questions were developed and are detailed in section 2.1. In this section, the developed sub-questions and main research question are answered.

Sub-question 1: What can be learned from existing LCAs of plastic and MSW management for a better elaboration of an LCA of MPW management options in Lima, Peru?

The study started with a systematic review of existing LCA studies of MSW and / or MPW management. The review aimed to collect and compile process data to be used during the elaboration of the LCA study for Lima and to evaluate and determine relevant key parameters when LCA studies of waste management are performed.

The approach of starting the study with a systematic review allowed a better understanding of the more important parameters when LCA of waste management is conducted. Also, the review allowed the identification of those aspects that were missing in most of the studies: more transparency during reporting, sensitivity analysis of important modelling choices (i.e. chosen allocation method), clear identification of the inclusions and exclusions in the system under study, among others. Thus, starting a study with a systematic review of existing studies, especially when there is lack of local and reliable data to be used to perform the LCA, is a useful approach and gives more understanding of how to guide the assessment to obtain more reliable results.

Sub-question 2: What are the key parameters in these existing LCAs and should – and if so, how - these parameters be changed for the Peruvian context?

The key parameters revealed during the systematic review were the method chosen to solve multifunctionality problems, the type of electricity mix assumed to be substituted and the assumed replacement ratio of recycled materials. Additionally, the case study also discovered other relevant key parameters, which were the assumed transport distance and the assumed LFG collected.

Some studies performed a sensitivity analysis of the type of electricity mix assumed and the replacement ratio assumed, but none of the studies evaluated the sensitivity of the results to the method chosen to solve the multifunctionality problem, assumed transport distances or assumed LFG collected. All of the evaluated studies only chose the substitution method to solve multifunctionality.

It is important to mention that the evaluated studies showed that there is still some confusion related to some concepts and definitions on LCA terms. This was noted for example during the definition of multifunctionality problems and solving options. LCA studies should provide a clear definition of multifunctionality problems faced during the study and clearly define the solving method and the possible influence of the method in the obtained results.

For the case study performed in this report the economic allocation method was initially chosen to solve the multifunctionality problem. Additionally, considering that all the selected studies applied the substitution method, this method was also applied in the case study. This allowed the comparison of the effects of both methods in the final results on the three scenarios.

When economic allocation was applied, the recycling scenario SC3 appeared as the best environmental option for all the nine impact categories, followed by the incineration scenario SC2. However, when the substitution method was chosen instead of the economic allocation method, the recycling scenario SC3 was preferred in eight out of nine categories. The incineration scenario SC2 became preferred for stratospheric ozone depletion, but became the least favourable for acidification, eutrophication, climate change, terrestrial, freshwater and human ecotoxicity

Another key parameter was the type of electricity mix assumed to be avoided when the substitution method was chosen. In the case study, the electricity mix for Lima was assumed to be hydropower-thermoelectric, which is an approximation of the real electricity mix of the country. To evaluate the effects of this assumption, a sensitivity analysis was performed evaluating the effects of assuming a type of electricity mix from hard coal. The sensitivity analysis showed that, when the type of electricity assumed to be avoided was from hard coal instead of from hydropower-thermoelectric, the incineration scenario SC2 became more environmentally preferable to recycling scenario SC3 and the baseline scenario SC1 for eutrophication and acidification. Also, SC2 became less preferable to SC1 only for climate change, freshwater ecotoxicity and human toxicity.

The assumed replacement ratio was another key parameter evaluated in the study during the application of both allocation methods to solve multifunctionality. When economic allocation was chosen, the effect of changing the replacement ratio from 1:1 to 1:0.5 were minimal. This is because the difference in prices between the goods and the wastes are big and a reduction of 50% on the prices of goods did not affect the allocation factors of the functional flows much.

When a replacement ratio of 1:0.5 was applied together with substitution allocation, the positive environmental impacts assigned to mechanical recycling were reduced in six impact categories by around 40%. Still, the recycling scenario remained the better option for eight out of nine impact categories, except for the case of stratospheric ozone depletion where incineration scenario SC2 remained the best option.

The study also considered a sensitivity analysis of the assumed transport distances. During the systematic review, it was observed that the collection and transport stages were mentioned as not significant. However, the case study showed that in the three scenarios, the impacts of the collection and transport stages together were responsible for around 50% for most of the impact categories. The sensitivity analysis evaluated the effects of increasing the transport distance by 10 km in SC3. This analysis showed that with this increase, the scenario SC3 became less preferable to scenario SC2 in five categories and less preferable to scenario SC1 in one category.

Another important finding of this study was the sensitivity of the results of scenario SC1 when LFG were assumed to be collected and flared. As a baseline, it was assumed that the collection of LFG in Peruvian landfills was 0%, which is closely related to reality. To evaluate the effects of this assumption, the percentage of collected LFG was increased to 47% instead of 0%. This assumption affected the results of photochemical oxidation and climate change, reducing the potential impacts by 15% and 10%, respectively. Thus, it is important to introduce systems of LFG collection in sanitary landfills, which would reduce the amount of GHG emissions.

Sub-question 3: Taking an environmental life cycle perspective, what is the environmental preference hierarchy of MPW management options for the Lima context as alternative to the current practice of open dumps?

All these sensitivity analyses showed that the final results depend on modelling decisions and main assumptions made during the study. The baseline characterization results showed the recycling scenario as the preferable option for all impact categories. However, the sensitivity analyses showed that when changes were performed in the initial assumptions, the recycling scenario was not maintained as the best option for all the impact categories, although was still the best option for most of them.

It is also important to mention that even though the impacts of open dumps were estimated as low for most impact categories, they are bigger in reality. There is a lack of data related to the real environmental impacts of open dumps and the estimations done in this study gave only a rough estimate of the potential real impacts of disposing MPW in open dumps, water bodies or the ocean.

Sub-question 4: How can the application of LCA of waste management help decision makers in choosing better management options?

LCA is considered as an ideal method for evaluating the environmental implications of waste management options. An LCA of waste management helps revealing important parameters that should be further considered when making decisions to improve the current MSW management system.

From the characterization results and sensitivity analysis it can be concluded that, even though the recycling scenario was not maintained as the best option for all the impact categories when assumptions were changed, it was the best option for most of them.

One way of making the recycling scenario more environmentally preferable is by improving the collection and transport system of MPW in Lima. As observed in the results, the collection and transport stages had a big influence on the final results. Therefore, implementing a recycling scheme for MPW in Lima with a reformulation of the collection and transport system could improve the potential environmental benefits that the recycling scenario has. The improvement of the collection and transport system would mean a reduction on environmental impacts, making the recycling scenario an even better option compared to the baseline scenario or an incineration scenario.

Collection and transport systems can be improved by optimizing collection routes and schedules, and by including collection points on areas with low access. More studies on how to improve collection and transport systems are highly recommended, in order to find the most efficient way for reducing distances during these stages.

Even though MSW management is normally seen as a total responsibility of the municipalities and local authorities, there are many more stakeholders that need to be involved in order to develop a successful recycling scheme for MPW. One of these stakeholders are the citizens. Citizens need to gain awareness related to the benefits of better MSW management, in relation to the environment and public health. Policy makers should also focus on developing education programs to improve the understanding of the importance of their participation in the separation and segregation of waste.

Separation at source brings benefits for recycling activities. More quantities of MSW can be recuperated in better shape with less contamination, which increases the value of the recuperated waste and the effectiveness of the recycling procedure. Also, by separating at source, the amount of waste that needs to be treated or sent to landfills is reduced, which also reduces the use of landfills and open dumps.

Also, as mentioned during the evaluation of the current waste management systems of Peru, Lima has an informal recycling sector. These informal recyclers or "waste pickers" collect plastic waste and other valuable waste to sell it and earn a small revenue from it. Policy makers should consider this informal sector as a starting point for improving plastic recycling. Also, policy makers should be aware that the informal collection and sell of plastic waste represent the main income of a large number of families. Thus, these waste pickers should not be eliminated but organized, trained and integrated into local programs. Decision makers and local authorities should be also aware that a recycling scheme involves the generation of jobs that would impact the local communities in a positive way.

Another key parameter that decision makers should look into is the importance of implementing LFG collection systems. Increasing the collection of LFG results in the reduction of environmental impacts on photochemical oxidation and climate change. The transition towards a recycling scheme on big cities takes time, and the implementation of collection of LFG would help with the reduction of environmental impacts during this transition.

Even though in the case study open dumps were included as part of the scenario SC1, they should be avoided by all means. Open dumps have an enormous impact on the environment and on society, including the increase of soil degradation, flooding risks, pollution of water bodies and air, hygienic risks and direct exposure to pathogens and other hazardous substances to surrounding inhabitants, among others. Even though the actual impacts of disposing MPW in open dumps are being underestimated in this study, these impacts are visible to the Peruvian community and are a reality for the country. Efforts to improve the MPW management of the country must also aim at eliminating the use of open dumps as disposal spaces.

Main research question: Based on existing LCAs of MPW and MSW management, and focused on the Peruvian context, what is the environmentally best waste management strategy for Lima (Peru) as an alternative to the current practice of open dumps and landfills?

After answering the previous four sub-questions, it can be concluded that the best waste management strategy for the city of Lima is the implementation of a recycling scheme in addition with an improvement on the collection and transport system of MSW.

The results of the case study showed the dependency of the results on the modelling decisions and main assumptions. The baseline characterization results showed first that the recycling scenario was more environmentally preferable to the incineration and the baseline scenario. The sensitivity analyses evaluated the robustness of these first results. These analyses showed that even though the results changed when assumptions were modified, the recycling scenario was maintained as the best option for most of the selected impact categories.

The contribution and sensitivity analyses also showed the importance of the collection and transport schemes on the resulting environmental impacts. Thus, more efficient systems of collection and transport that could reduce the distances travelled would mean a reduction of the impacts on the environment. This improvement in the collection and transport systems should be part of the main decisions taken by the authorities in Peru.

8.2 Recommendations

The study showed the importance of improving the collection and transport systems. Variations on the transport distances affect directly the performance of the scenarios in general. Therefore, it is important to take the influence of transport into consideration in the overall impacts of the scenarios and propose a better and more efficient collection and transport systems for MSW in the city.

Landfills will still be necessary in the future, because not all collected waste can be recycled or incinerated. Thus, it is important that the existing landfills in Lima, and in Peru, are improved. It is recommended that landfills are located far from human settlement and that they are properly covered and sealed to avoid contaminants entering the surrounding environment. Another improvement for sanitary landfills is the inclusion of LFG collection systems, which would help reducing GHG emissions to the environment. The collection systems may also need energy to function and would also have an impact by themselves. However, collection systems could also be connected to power plants and generate energy from the collected LFG. Thus, decision makers should not only eliminate the use of open dumps, but also improve the existing sanitary landfills by implementing these gas collection systems.

In relation to the data used in this case study, the background data used to model the selected scenarios were retrieved from the database Ecoinvent v2.2 (2010). This data was mainly retrieved from European countries, which may not be completely representative of the current situation in developing countries. An adaptation of the used data to resemble the current situation of Peru is recommended for future research, to obtain more representative results.

In relation to the use of LCA to evaluate MSW management scenarios, this study revealed that the results are directly affected by the method chosen to solve the multifunctionality problem. Therefore, it is important that when analysing MSW management system, a sensitivity analysis is performed to evaluate how different choices of solving multifunctionality affect the results, and how robust the results are for these changes.

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Appendix B: Inventory data of case study

Scenario SC1

Process = [P4088] SC1 Collection of MPW — **Original data**

Description = Assumption: From ecoinvent process G185, 1tkm uses 0.336 kg diesel. Adapted from Nishijama et al. 2012

Economic inflows

Label	Name	Value	Unit
[G185]	transport, municipal waste collection, lorry 21t[CH]	84.8	tkm
[W4088]	SC1 generated plastic waste	1000	kg

Original data:

0.032 L/kg Density of fuel oil: 890.13 kg/m3

28.5 kg Diesel /1000kg waste

Transforming kg diesel to tkm

From ecoinvent: 1tkm uses 0.336 kg diesel

Economic outflows

Label	Name	Value	Unit
[W4089]	SC1 collected MPW	1000	kg

Process = [P4089] SC1 Compaction of MPW — **Original data**

Description = Assumption: From ecoinvent process G185, 1tkm uses 0.336 kg diesel. Adapted from Nishijama et al. 2012

Economic inflows

Label	Name	Value	Unit
[G185]	transport, municipal waste collection, lorry 21t[CH]	19.4	tkm
[G1767]	electricity, natural gas, at combined cycle plant, best	46.8	kWh
[G2948]	electricity, hydropower, at reservoir power plant[BR]	46.8	kWh
[W4089]	SC1 collected MPW	1000	kg

Original data:

0.0073 L/kg Density of fuel oil: 890.13 kg/m3

0.09358 kWh/kg

Assumption: Peruvian electricity 50% hidro 50% thermo

Transforming kg diesel to tkm

From ecoinvent: 1tkm uses 0.336 kg diesel

6.53 kg Diesel/1000kg waste

* Nishijama et al. 2012 mention 0.008L of diesel and 0.102kWh per 1.09kg of waste

Economic outflows

Label	Name	Value	Unit
[W4090]	SC1 compacted MPW	1000	kg

Appendix B: Inventory data of case study

Process = [P4090] SC1 Transport and transfer MPW				Original data				
Description = Transfer diesel and energy consumption adapted from Diaz and Warith (2006)								
Economic inflows								
Label	Name	Value	Unit					
[G185]	transport, municipal waste collection, lorry 21t[CH]	50	tkm					
[G651]	diesel, at regional storage[RER]	0.111	kg	0.125	L/t	Density of fuel oil:	890.13	kg/m3
[G1767]	electricity, natural gas, at combined cycle plant, best	1.25	kWh	2.5	kWh/t			
[G2948]	electricity, hydropower, at reservoir power plant[BR]	1.25	kWh					
[W4090]	SC1 compacted MPW	1000	kg					
Economic outflows								
Label	Name	Value	Unit					
[W4091]	SC1 transfered MPW	1000	kg					

Process = [P4091] SC1 Disposal of MPW in landfill and open dump			
Description = Sanitary landfill with 0% LFG capture and 100% direct LFG emissions. 75% of plastic waste goes to sanitary landfill and 25% goes to open dump			
Economic inflows			
Label	Name	Value	Unit
[W4091]	SC1 transfered MPW	1000	kg
[G4092]	SC1 disposal of MPW into open dump - leachate	250	kg
[G4093]	SC1 disposal of MPW into an open dump - LFG	250	kg
[G4094]	SC1 Copy of disposal, plastics, mixture, 15.3% water,	750	kg

Appendix B: Inventory data of case study

Process = [P4092] SC1 Opendump leachate emissions to groundwater per kg of MPW

Description = Estimates of emissions of 1kg of plastics in an opendump, based on untreated leachate on a sanitary landfill

Economic outflows

Label	Name	Value	Unit
[G4092]	SC1 disposal of MPW into open dump - leachate	1	kg

Environmental emissions

Label	Name	Value	Unit
[E190]	Nitrate[water_ground-]	1.38E-06	kg
[E200]	Cadmium, ion[water_ground-]	1.33E-07	kg
[E1313]	Vanadium, ion[water_ground-]	2.84E-07	kg
[E1647]	Nitrite[water_ground-]	9.65E-07	kg

Process = [P4093] SC1 LFG emissions per kg of MPW

Description = Open dump LFG emissions from the disposal of 1kg of plastic waste. Estimated from emissions of a sanitary landfill

Economic outflows

Label	Name	Value	Unit
[G4093]	SC1 disposal of MPW into an open dump - LFG	1	kg

Environmental emissions

Label	Name	Value	Unit
[E12]	Carbon dioxide, fossil[air_low population density]	0.00994	kg
[E221]	Sulfur dioxide[air_low population density]	1.84E-06	kg
[E881]	Vanadium[air_low population density]	7.09E-11	kg
[E1035]	Heat, waste[soil_industrial]	0.238	MJ
[E1171]	Heat, waste[water_ground-, long-term]	33.7	MJ

Appendix B: Inventory data of case study

Process = [P4094] SC1 Copy of disposal, plastics, mixture, 15.3% water, to sanitary landfill[CH]

Description = Difference: 100% of LFG emitted directly to the atmosphere.

Inventoried waste contains 100% Mixed various plastics

Economic inflows

Label	Name	Value	Unit
[G11]	transport, lorry 20-28t, fleet average[CH]	3.89E-06	tkm
[G2339]	wastewater treatment plant, class 3[CH]	1.42E-11	unit

Economic outflows

Label	Name	Value	Unit
[G4094]	SC1 Copy of disposal, plastics, mixture, 15.3% water,	1	kg

Environmental emissions

Label	Name	Value	Unit	**Original value (47% captured 53% direct emitted)**	
[E12]	*Carbon dioxide, fossil[air_low population density]*	0.00994	kg	0.01586	kg
[E222]	*Methane, fossil[air_low population density]*	0.00459	kg	0.00243	kg
[E1035]	*Heat, waste[soil_industrial]*	0.238	MJ	0.19983	MJ
	Carbon monoxide, fossil[air_low population density]	0	kg	9E-07	kg
	NMVOC, non-methane volatile organic compounds, u	0	kg	1.7E-08	kg
	Particulates, < 2.5 um[air_low population density]	0	kg	3E-07	kg
	Nitrogen oxides[air_low population density]	0	kg	3.9E-08	kg
	Heat, waste[air_low population density]	0	MJ	0.08627	MJ

*Only showing the changed environmental emissions

*Only showing the changed environmental emissions

Appendix B: Inventory data of case study

Scenario SC2

Process = [P4095] SC2 Collection of MPW | **Original data**

Description = Adapted from Nishijama et al. 2012

Economic inflows

Label	Name	Value	Unit
[G185]	transport, municipal waste collection, lorry 21t[CH]	84.8	tkm
[W4095]	SC2 generated MPW	1000	kg

Original data:

0.032	L/kg	Density of fuel oil:	890.13	kg/m3
28.5	kg Diesel /1000kg waste			

Transforming kg diesel to tkm

From ecoinvent: 1tkm uses 0.336 kg diesel

Economic outflows

Label	Name	Value	Unit
[W4096]	SC2 collected MPW	1000	kg

Process = [P4096] SC2 Compaction of MPW | **Original data**

Description = Adapted from Nishijama et al. 2012

Economic inflows

Label	Name	Value	Unit
[G185]	transport, municipal waste collection, lorry 21t[CH]	19.4	tkm
[G1767]	electricity, natural gas, at combined cycle plant, best	46.8	kWh
[G2948]	electricity, hydropower, at reservoir power plant[BR]	46.8	kWh
[W4096]	SC2 collected MPW	1000	kg

Original data:

0.0073	L/kg	Density of fuel oil:	890.13	kg/m3
0.09358	kWh/kg			

Assumption: Peruvian electricity 50% hidro 50% thermo

Transforming kg diesel to tkm

From ecoinvent: 1tkm uses 0.336 kg diesel

6.53 kg Diesel/1000kg waste

* Nishijama et al. 2012 mention 0.008L of diesel and 0.102kWh per 1.09kg of waste

Economic outflows

Label	Name	Value	Unit
[W4097]	SC2 compacted MPW	1000	kg

Appendix B: Inventory data of case study

Process = [P4097] SC2 Transport and transfer of MPW				**Original data**				
Description = Transfer diesel and energy consumption adapted from Diaz and Warith (2006)								
Economic inflows								
Label	Name	Value	Unit					
[G185]	transport, municipal waste collection, lorry 21t[CH]	50	tkm					
[G651]	diesel, at regional storage[RER]	0.111	kg	0.125	L/t	Density of fuel oil:	890.13	kg/m3
[G1767]	electricity, natural gas, at combined cycle plant, best	1.25	kWh	2.5	kWh/t			
[G2948]	electricity, hydropower, at reservoir power plant[BR]	1.25	kWh					
[W4097]	SC2 compacted MPW	1000	kg					
Economic outflows								
Label	Name	Value	Unit					
[W4098]	SC2 transfered MPW	1000	kg					

Process = [P4098] SC2 Incineration of MPW				**Original data**	
Description = From MPW description in Lima: 43.5% are bags, here considered as LDPE, 25.3% are PET plastics, 31.3% are hard plastics. Hard plastics are PP, PE, PS and PVC in equal parts					
Economic inflows					
Label	Name	Value	Unit		
[G672]	disposal, polystyrene, 0.2% water, to municipal incine	78.3	kg	PS	78
[G834]	disposal, polyethylene, 0.4% water, to municipal incir	513.3	kg	HDPE	78
[G884]	disposal, polyvinylchloride, 0.2% water, to municipal	78.3	kg	PVC	78
[G2140]	disposal, polypropylene, 15.9% water, to municipal in	78.3	kg	PP	78
[G2321]	disposal, polyethylene terephtalate, 0.2% water, to m	253.0	kg	PET	253
[W4098]	SC2 transfered MPW	1000	kg	LDPE	435

Appendix B: Inventory data of case study

Economic outflows

Label	Name	Value	Unit						
				Price: 0.55 soles/kwh					
[G4099]	SC2 energy from waste	1115.4	kWh						
	From PS	*98.0*	*kWh*	4.51	MJ/kg	1.25242698	kWh/kg	9.04995	thermal
	From PE	*713.2*	*kWh*	5.00	MJ/kg	1.38966835	kWh/kg	10.022	thermal
	From PVC	*49.5*	*kWh*	2.28	MJ/kg	0.63289873	kWh/kg	4.66211	thermal
	From PP	*81.4*	*kWh*	3.74	MJ/kg	1.03978664	kWh/kg	7.54391	thermal
	From PET	*173.2*	*kWh*	2.46	MJ/kg	0.68468273	kWh/kg	5.02887	thermal

Scenario SC3

Process = [P4099] SC3 Collection of MPW **Original data**

Description = Adapted from Nishijama et al. 2012

Economic inflows

Label	Name	Value	Unit					
[G185]	transport, municipal waste collection, lorry 21t[CH]	84.8	tkm	0.032	L/kg	Density of fuel oil:	890.13	kg/m3
[W4100]	SC3 generated MPW	1000	kg	28.5	kg Diesel /1000kg waste			
				Transforming kg diesel to tkm				
				From ecoinvent: 1tkm uses		0.336	kg diesel	

Economic outflows

Label	Name	Value	Unit
[W4101]	SC3 collected MPW	1000	kg

Appendix B: Inventory data of case study

Process = [P4100] SC3 Compaction and transport of MPW				**Original data**
Description = Adapted from Nishijama et al. 2012				
Economic inflows				
Label	Name	Value	Unit	
[G185]	transport, municipal waste collection, lorry 21t[CH]	50	tkm	
[G185]	transport, municipal waste collection, lorry 21t[CH]	19.4	tkm	0.0073 L/kg Density of fuel oil: 890.13 kg/m3
[G1767]	electricity, natural gas, at combined cycle plant, best	46.8	kWh	0.09358 kWh/kg
[G2948]	electricity, hydropower, at reservoir power plant[BR]	46.8	kWh	Assumption: Peruvian electricity 50% hidro 50% thermo
[W4101]	SC3 collected MPW	1000	kg	**Transforming kg diesel to tkm**
				From ecoinvent: 1tkm uses 0.336 kg diesel
				6.53 kg Diesel/1000kg waste
				* Nishijama et al. 2012 mention 0.008L of diesel and 0.102kWh per 1.09kg of waste
Economic outflows				
Label	Name	Value	Unit	
[W4102]	SC3 compacted MPW	1000	kg	

Process = [P4101] SC3 Manual separation of MPW				**Original data**
Description =				
Economic inflows				
Label	Name	Value	Unit	
[W4102]	SC3 compacted MPW	1000	kg	
Economic outflows				
Label	Name	Value	Unit	
[W4103]	SC3 plastic bags and films	435	kg	
[W4104]	SC3 hard plastics & PET bottles	565	kg	

Appendix B: Inventory data of case study

Process = [P4102] SC3 Sorting and mechanical recycling of MPW				Original data		
Description = Sorting: Adapted from Shonfield (2008). Pellenc use NIR sorting technology to separate out the different plastic fractions. Mechanical recycling: Adapted from Nishijama et al. 2012						
Sorting of MPW				To separate out the four major polymers (PE, PP, PET and PVC) two machines are required – both operating in ternary mode.		
Economic inflows						
Label	Name	Value	Unit	*Power consumption (per unit)*		
[G1767]	electricity, natural gas, at combined cycle plant, best	25.5	kWh	6*3	kW	*Compressed air (ternary mode - 2 sorts)*
[G2948]	electricity, hydropower, at reservoir power plant[BR]	25.5	kWh	11*3	kW	
[W4103]	SC3 plastic bags and films	435	kg	51	kWh/t	Total
[W4104]	SC3 hard plastics & PET bottles	565	kg	Assumption: all LDPE plastics		
	PET plastic	*252.6*	*kg*	25.60%	of all MPW in Lima (Source: SIGERSOL)	
	PP plastic	*78.1*	*kg*	Assumption: 25% of all "hard plastics"		
	PVC plastic	*78.1*	*kg*	Assumption: 25% of all "hard plastics"		
	PS plastic	*78.1*	*kg*	Assumption: 25% of all "hard plastics"		
	HDPE plastic	*78.1*	*kg*	Assumption: 25% of all "hard plastics"		
Economic outflows						
Label	Name	Value	Unit	**Manual**	***NIR Separation Efficiency***	
	SC3 PET plastic	*240.0*	*kg*	95.00%	76.90%	
	SC3 PP plastic	*74.2*	*kg*	95.00%	80.30%	
	SC3 PVC plastic	*74.2*	*kg*	95.00%	81.20%	
	SC3 PS plastic	*74.2*	*kg*	95.00%	64.70%	
	SC3 HDPE plastic	*74.2*	*kg*	95.00%	67.40%	
	SC3 LDPE plastic	*413.3*	*kg*	95.00%	67.40%	
[W4105]	SC3 unsorted from NIR and manual separation	50.0	kg			

Appendix B: Inventory data of case study

Mechanical recycling of MPW				**Original data**				
Description = Adapted from Nishijama et al. 2012								
Economic inflows								
Label	Name	Value	Unit					
[G71]	tap water, at user[RER]	1900	kg	0.002	m3/kg			
[G220]	sodium hydroxide, 50% in H2O, production mix, at pl	8.55	kg	0.009	kg/kg			
[G651]	diesel, at regional storage[RER]	1.69	kg	0.002	L/kg	Bunker C oil (Diesel assumed)		
[G1767]	electricity, natural gas, at combined cycle plant, best	308	kWh	0.649	kWh/kg	Density of fuel oil:	890.13	kg/m3
[G2039]	waste paper sorting plant[RER]	6.06E-07	unit					
[G2948]	electricity, hydropower, at reservoir power plant[BR]	308	kWh					
	SC3 PET plastic	*240.0*	*kg*					
	SC3 PP plastic	*74.2*	*kg*					
	SC3 PVC plastic	*74.2*	*kg*					
	SC3 PS plastic	*74.2*	*kg*					
	SC3 HDPE plastic	*74.2*	*kg*					
	SC3 LDPE plastic	*413.3*	*kg*					
Economic outflows								
Label	Name	Value	Unit	0.9	kg	Asumption 10% losses		
[G4106]	SC3 PET pellets	216	kg					
[G4107]	SC3 PP pellets	66.8	kg					
[G4108]	SC3 PVC pellets	66.8	kg					
[G4109]	SC3 PS pellets	66.8	kg					
[G4110]	SC3 HDPE pellets	66.8	kg					
[G4111]	SC3 LDPE pellets	372	kg					
[W4112]	SC3 losses from mechanical recycling	95	kg	0.1	kg	Assumption 10% losses		

Appendix B: Inventory data of case study

Process = [P4103] SC3 Incineration of losses and unsorted plastics **Original data**

Description =

Economic inflows

Label	Name	Value	Unit
[G69]	disposal, plastics, mixture, 15.3% water, to municipal	145	kg
[W4105]	SC3 unsorted plastics from NIR and manual separati	50	kg
[W4112]	SC3 losses from mechanical recycling	95	kg

Economic outflows

Label	Name	Value	Unit					
[G4113]	SC3 energy from waste	140.22	kWh	3.48	MJ/kg	0.967	kWh/kg	from Ecoinvent

Appendix C: Results of inventory analysis

Alternative = [A1] Output of [W4088] SC1 generated MPW

Label	Elementary flows	Value	Unit
[E1]	Occupation, industrial area, built up[resource_land]	-0.019	m2a
[E2]	Occupation, construction site[resource_land]	-0.195	m2a
[E3]	Transformation, from unknown[resource_land]	-0.00982	m2
[E4]	Transformation, to industrial area, built up[resource_land]	-0.00059	m2
[E5]	Occupation, urban, discontinuously built[resource_land]	-1.04E-05	m2a
[E6]	Transformation, from pasture and meadow[resource_land]	-0.0458	m2
[E7]	Transformation, to urban, discontinuously built[resource_land]	-2.08E-07	m2
[E8]	Heat, waste[air_low population density]	276	MJ
[E9]	Energy, solar, converted[resource_in air]	-0.021	MJ
[E10]	Heat, waste[air_high population density]	392	MJ
[E11]	NMVOC, non-methane volatile organic compounds, unspecified origin[air_high population density]	0.536	kg
[E12]	Carbon dioxide, fossil[air_low population density]	26.4	kg
[E13]	Ammonia[air_high population density]	0.00139	kg
[E14]	Nitrogen oxides[air_high population density]	1.2	kg
[E15]	Particulates, < 2.5 um[air_high population density]	0.0976	kg
[E16]	Particulates, > 10 um[air_high population density]	0.0285	kg
[E17]	Particulates, > 2.5 um, and < 10um[air_high population density]	0.0169	kg
[E18]	Zinc, ion[water_river]	0.000258	kg
[E19]	Lead[water_river]	1.29E-05	kg
[E20]	Nickel, ion[water_river]	8.18E-06	kg
[E21]	Mercury[water_river]	1.60E-07	kg
[E22]	Copper, ion[water_river]	5.67E-06	kg
[E23]	Chromium, ion[water_river]	5.79E-06	kg
[E24]	Cadmium, ion[water_river]	5.13E-05	kg
[E25]	Arsenic, ion[water_river]	1.32E-05	kg
[E26]	Phosphate[water_river]	2.46E-05	kg
[E27]	Ammonium, ion[water_river]	0.0556	kg
[E28]	Nitrate[water_river]	0.202	kg
[E29]	Nitrate[air_high population density]	3.01E-08	kg
[E30]	Calcite, in ground[resource_in ground]	-1.61	kg
[E31]	Sylvite, 25 % in sylvinite, in ground[resource_in ground]	-1.28E-04	kg
[E32]	Water, cooling, unspecified natural origin[resource_in water]	-0.483	m3
[E33]	Water, river[resource_in water]	-0.275	m3
[E34]	Sodium, ion[water_river]	0.848	kg
[E35]	Potassium, ion[water_river]	0.0116	kg
[E36]	Chloride[water_river]	1.68	kg
[E37]	Calcium, ion[water_river]	0.0822	kg
[E38]	Magnesium[water_river]	0.0139	kg
[E39]	Sulfur[water_river]	0.000461	kg
[E40]	Hydrogen chloride[air_high population density]	0.000152	kg
[E41]	Hydrogen fluoride[air_high population density]	1.12E-05	kg
[E42]	Methane, biogenic[air_high population density]	3.41E-05	kg
[E43]	Carbon monoxide, fossil[air_high population density]	0.43	kg
[E44]	Carbon dioxide, biogenic[air_high population density]	0.259	kg
[E45]	Carbon dioxide, fossil[air_high population density]	196	kg
[E46]	Dinitrogen monoxide[air_high population density]	0.00891	kg
[E47]	Hydrogen sulfide[air_high population density]	2.24E-07	kg
[E48]	Occupation, industrial area[resource_land]	-0.143	m2a
[E49]	Transformation, to industrial area[resource_land]	-0.00036	m2
[E50]	Acetic acid[air_high population density]	5.53E-05	kg
[E51]	Chlorine[air_high population density]	2.68E-05	kg
[E52]	Chloroacetic acid[air_high population density]	6.70E-09	kg
[E53]	Chlorosulfonic acid[air_high population density]	2.32E-11	kg
[E54]	Cyanoacetic acid[air_high population density]	1.90E-11	kg
[E55]	Benzene, dichloro[air_high population density]	6.52E-11	kg
[E56]	Dimethyl malonate[air_high population density]	2.38E-11	kg
[E57]	Ethanol[air_high population density]	5.60E-06	kg
[E58]	Hydrogen[air_high population density]	0.000138	kg
[E59]	Methane, fossil[air_high population density]	0.0222	kg
[E60]	Methanesulfonic acid[air_high population density]	1.92E-11	kg
[E61]	Methanol[air_high population density]	8.22E-06	kg
[E62]	Methane, dichloro-, HCC-30[air_high population density]	6.51E-10	kg
[E63]	Methyl amine[air_high population density]	3.08E-11	kg
[E64]	Propanol[air_high population density]	3.93E-10	kg
[E65]	Propene[air_high population density]	0.000177	kg
[E66]	Sulfur dioxide[air_high population density]	0.0774	kg
[E67]	Sulphur trioxide[air_high population density]	5.73E-10	kg

Alternative = [A2] Output of [W4094] SC2 generated MPW

Label	Elementary flows	Value	Unit
[E1]	Occupation, industrial area, built up[resource_land]	-0.0161	m2a
[E2]	Occupation, construction site[resource_land]	-0.00739	m2a
[E3]	Transformation, from unknown[resource_land]	-0.00505	m2
[E4]	Transformation, to industrial area, built up[resource_land]	-0.00048	m2
[E5]	Occupation, urban, discontinuously built[resource_land]	-9.89E-06	m2a
[E6]	Transformation, from pasture and meadow[resource_land]	-0.00058	m2
[E7]	Transformation, to urban, discontinuously built[resource_land]	-1.97E-07	m2
[E8]	Heat, waste[air_low population density]	263	MJ
[E9]	Energy, solar, converted[resource_in air]	-0.0208	MJ
[E10]	Heat, waste[air_high population density]	1.53E+03	MJ
[E11]	NMVOC, non-methane volatile organic compounds, unspecified origin[air_high population density]	0.537	kg
[E12]	Carbon dioxide, fossil[air_low population density]	16.6	kg
[E13]	Ammonia[air_high population density]	0.00173	kg
[E14]	Nitrogen oxides[air_high population density]	1.21	kg
[E15]	Particulates, < 2.5 um[air_high population density]	0.0977	kg
[E16]	Particulates, > 10 um[air_high population density]	0.0283	kg
[E17]	Particulates, > 2.5 um, and < 10um[air_high population density]	0.0167	kg
[E18]	Zinc, ion[water_river]	0.000192	kg
[E19]	Lead[water_river]	1.04E-05	kg
[E20]	Nickel, ion[water_river]	3.01E-06	kg
[E21]	Mercury[water_river]	2.46E-07	kg
[E22]	Copper, ion[water_river]	2.72E-06	kg
[E23]	Chromium, ion[water_river]	7.39E-06	kg
[E24]	Cadmium, ion[water_river]	9.06E-07	kg
[E25]	Arsenic, ion[water_river]	4.61E-05	kg
[E26]	Phosphate[water_river]	3.74E-05	kg
[E27]	Ammonium, ion[water_river]	0.000263	kg
[E28]	Nitrate[water_river]	0.0021	kg
[E29]	Nitrate[air_high population density]	2.97E-08	kg
[E30]	Calcite, in ground[resource_in ground]	-1.9	kg
[E31]	Sylvite, 25 % in sylvinite, in ground[resource_in ground]	-1.25E-04	kg
[E32]	Water, cooling, unspecified natural origin[resource_in water]	-0.595	m3
[E33]	Water, river[resource_in water]	-0.308	m3
[E34]	Sodium, ion[water_river]	0.77	kg
[E35]	Potassium, ion[water_river]	0.0109	kg
[E36]	Chloride[water_river]	2.84	kg
[E37]	Calcium, ion[water_river]	0.0795	kg
[E38]	Magnesium[water_river]	0.0131	kg
[E39]	Sulfur[water_river]	0.000442	kg
[E40]	Hydrogen chloride[air_high population density]	0.000149	kg
[E41]	Hydrogen fluoride[air_high population density]	1.06E-05	kg
[E42]	Methane, biogenic[air_high population density]	1.34E-05	kg
[E43]	Carbon monoxide, fossil[air_high population density]	0.436	kg
[E44]	Carbon dioxide, biogenic[air_high population density]	0.238	kg
[E45]	Carbon dioxide, fossil[air_high population density]	304	kg
[E46]	Dinitrogen monoxide[air_high population density]	0.00909	kg
[E47]	Hydrogen sulfide[air_high population density]	2.00E-07	kg
[E48]	Occupation, industrial area[resource_land]	-0.137	m2a
[E49]	Transformation, to industrial area[resource_land]	-0.00036	m2
[E50]	Acetic acid[air_high population density]	5.63E-05	kg
[E51]	Chlorine[air_high population density]	5.14E-05	kg
[E52]	Chloroacetic acid[air_high population density]	6.61E-09	kg
[E53]	Chlorosulfonic acid[air_high population density]	2.22E-11	kg
[E54]	Cyanoacetic acid[air_high population density]	1.82E-11	kg
[E55]	Benzene, dichloro[air_high population density]	6.14E-11	kg
[E56]	Dimethyl malonate[air_high population density]	2.28E-11	kg
[E57]	Ethanol[air_high population density]	5.91E-06	kg
[E58]	Hydrogen[air_high population density]	0.000541	kg
[E59]	Methane, fossil[air_high population density]	0.0182	kg
[E60]	Methanesulfonic acid[air_high population density]	1.84E-11	kg
[E61]	Methanol[air_high population density]	1.00E-05	kg
[E62]	Methane, dichloro-, HCC-30[air_high population density]	5.71E-10	kg
[E63]	Methyl amine[air_high population density]	3.14E-11	kg
[E64]	Propanol[air_high population density]	3.83E-10	kg
[E65]	Propene[air_high population density]	0.000166	kg
[E66]	Sulfur dioxide[air_high population density]	0.075	kg
[E67]	Sulphur trioxide[air_high population density]	5.18E-10	kg

Alternative = [A3] Output of [W4099] SC3 generated MPW

Label	Elementary flows	Value	Unit
[E1]	Occupation, industrial area, built up[resource_land]	-0.0158	m2a
[E2]	Occupation, construction site[resource_land]	-0.00676	m2a
[E3]	Transformation, from unknown[resource_land]	-0.00487	m2
[E4]	Transformation, to industrial area, built up[resource_land]	-0.00047	m2
[E5]	Occupation, urban, discontinuously built[resource_land]	-9.72E-06	m2a
[E6]	Transformation, from pasture and meadow[resource_land]	-0.00046	m2
[E7]	Transformation, to urban, discontinuously built[resource_land]	-1.94E-07	m2
[E8]	Heat, waste[air_low population density]	248	MJ
[E9]	Energy, solar, converted[resource_in air]	-0.0174	MJ
[E10]	Heat, waste[air_high population density]	373	MJ
[E11]	NMVOC, non-methane volatile organic compounds, unspecified origin[air_high population density]	0.535	kg
[E12]	Carbon dioxide, fossil[air_low population density]	15.2	kg
[E13]	Ammonia[air_high population density]	0.00128	kg
[E14]	Nitrogen oxides[air_high population density]	1.2	kg
[E15]	Particulates, < 2.5 um[air_high population density]	0.0974	kg
[E16]	Particulates, > 10 um[air_high population density]	0.0283	kg
[E17]	Particulates, > 2.5 um, and < 10um[air_high population density]	0.0167	kg
[E18]	Zinc, ion[water_river]	0.000188	kg
[E19]	Lead[water_river]	9.68E-06	kg
[E20]	Nickel, ion[water_river]	2.70E-06	kg
[E21]	Mercury[water_river]	3.58E-08	kg
[E22]	Copper, ion[water_river]	2.44E-06	kg
[E23]	Chromium, ion[water_river]	5.34E-06	kg
[E24]	Cadmium, ion[water_river]	4.63E-07	kg
[E25]	Arsenic, ion[water_river]	9.82E-06	kg
[E26]	Phosphate[water_river]	2.31E-05	kg
[E27]	Ammonium, ion[water_river]	0.000206	kg
[E28]	Nitrate[water_river]	0.00043	kg
[E29]	Nitrate[air_high population density]	2.70E-08	kg
[E30]	Calcite, in ground[resource_in ground]	-1.18	kg
[E31]	Sylvite, 25 % in sylvinite, in ground[resource_in ground]	-1.19E-04	kg
[E32]	Water, cooling, unspecified natural origin[resource_in water]	-0.441	m3
[E33]	Water, river[resource_in water]	-0.273	m3
[E34]	Sodium, ion[water_river]	0.753	kg
[E35]	Potassium, ion[water_river]	0.0108	kg
[E36]	Chloride[water_river]	1.25	kg
[E37]	Calcium, ion[water_river]	0.0769	kg
[E38]	Magnesium[water_river]	0.013	kg
[E39]	Sulfur[water_river]	0.00044	kg
[E40]	Hydrogen chloride[air_high population density]	0.00012	kg
[E41]	Hydrogen fluoride[air_high population density]	9.81E-06	kg
[E42]	Methane, biogenic[air_high population density]	1.06E-05	kg
[E43]	Carbon monoxide, fossil[air_high population density]	0.427	kg
[E44]	Carbon dioxide, biogenic[air_high population density]	0.188	kg
[E45]	Carbon dioxide, fossil[air_high population density]	195	kg
[E46]	Dinitrogen monoxide[air_high population density]	0.00863	kg
[E47]	Hydrogen sulfide[air_high population density]	1.94E-07	kg
[E48]	Occupation, industrial area[resource_land]	-0.136	m2a
[E49]	Transformation, to industrial area[resource_land]	-0.00033	m2
[E50]	Acetic acid[air_high population density]	5.51E-05	kg
[E51]	Chlorine[air_high population density]	2.62E-05	kg
[E52]	Chloroacetic acid[air_high population density]	6.46E-09	kg
[E53]	Chlorosulfonic acid[air_high population density]	2.20E-11	kg
[E54]	Cyanoacetic acid[air_high population density]	1.80E-11	kg
[E55]	Benzene, dichloro[air_high population density]	6.07E-11	kg
[E56]	Dimethyl malonate[air_high population density]	2.26E-11	kg
[E57]	Ethanol[air_high population density]	5.10E-06	kg
[E58]	Hydrogen[air_high population density]	0.000144	kg
[E59]	Methane, fossil[air_high population density]	0.0178	kg
[E60]	Methanesulfonic acid[air_high population density]	1.82E-11	kg
[E61]	Methanol[air_high population density]	7.50E-06	kg
[E62]	Methane, dichloro-, HCC-30[air_high population density]	5.14E-10	kg
[E63]	Methyl amine[air_high population density]	2.89E-11	kg
[E64]	Propanol[air_high population density]	3.37E-10	kg
[E65]	Propene[air_high population density]	0.000165	kg
[E66]	Sulfur dioxide[air_high population density]	0.0738	kg
[E67]	Sulphur trioxide[air_high population density]	5.08E-10	kg

Appendix C: Results of inventory analysis

[E68]	t-Butylamine[air_high population density]	1.49E-11 kg
[E69]	Toluene[air_high population density]	0.00471 kg
[E70]	Acetic acid[water_river]	1.96E-06 kg
[E71]	Acetonitrile[water_river]	1.59E-11 kg
[E72]	Carbonate[water_river]	2.29E-05 kg
[E73]	Chloroacetic acid[water_river]	3.35E-07 kg
[E74]	Chlorosulfonic acid[water_river]	5.79E-11 kg
[E75]	o-Dichlorobenzene[water_river]	2.59E-08 kg
[E76]	Dimethylamine[water_river]	1.72E-10 kg
[E77]	Ethanol[water_river]	1.42E-07 kg
[E78]	Fluoride[water_river]	0.000266 kg
[E79]	Formate[water_river]	4.60E-09 kg
[E80]	Methanol[water_river]	3.91E-07 kg
[E81]	Methyl amine[water_river]	7.38E-11 kg
[E82]	Methane, dichloro-, HCC-30[water_river]	3.60E-05 kg
[E83]	Propanol[water_river]	3.58E-11 kg
[E84]	Propene[water_river]	1.46E-05 kg
[E85]	Sulfate[water_river]	0.0263 kg
[E86]	t-Butylamine[water_river]	3.59E-11 kg
[E87]	Toluene[water_river]	0.000307 kg
[E88]	Water, salt, sole[resource_in water]	-0.0408 m3
[E89]	Bromine, 0.0023% in water[resource_in water]	-7.55E-08 kg
[E90]	Iodine, 0.03% in water[resource_in water]	-1.98E-08 kg
[E91]	Toluene, 2-chloro[air_high population density]	2.44E-11 kg
[E92]	Acetaldehyde[air_high population density]	3.20E-06 kg
[E93]	Aniline[air_high population density]	4.97E-11 kg
[E94]	Diethylamine[air_high population density]	2.31E-11 kg
[E95]	Dipropylamine[air_high population density]	1.36E-11 kg
[E96]	Ethyl acetate[air_high population density]	1.65E-05 kg
[E97]	Lactic acid[air_high population density]	1.07E-11 kg
[E98]	Methyl lactate[air_high population density]	1.17E-11 kg
[E99]	Propanal[air_high population density]	1.38E-08 kg
[E100]	Toluene, 2-chloro[water_river]	4.73E-11 kg
[E101]	Acetaldehyde[water_river]	1.17E-07 kg
[E102]	Aniline[water_river]	1.21E-10 kg
[E103]	Bromide[water_river]	6.84E-08 kg
[E104]	Diethylamine[water_river]	5.55E-11 kg
[E105]	Dipropylamine[water_river]	3.28E-11 kg
[E106]	Ethyl acetate[water_river]	6.78E-11 kg
[E107]	Iodide[water_river]	0.000263 kg
[E108]	Lactic acid[water_river]	2.57E-11 kg
[E109]	Sulfide[water_river]	2.59E-06 kg
[E110]	Phenol, 2,4-dichloro[air_high population density]	7.71E-12 kg
[E111]	Butanol[air_high population density]	3.97E-12 kg
[E112]	Ethylene oxide[air_high population density]	1.07E-07 kg
[E113]	Phenol[air_high population density]	5.44E-07 kg
[E114]	Propane[air_high population density]	0.00382 kg
[E115]	Propionic acid[air_high population density]	5.31E-06 kg
[E116]	Butanol[water_river]	5.98E-08 kg
[E117]	Ethylene oxide[water_river]	1.13E-08 kg
[E118]	Phenol[water_river]	0.000216 kg
[E119]	Propionic acid[water_river]	2.94E-11 kg
[E120]	2-Aminopropanol[air_high population density]	1.88E-12 kg
[E121]	Acetone[air_high population density]	7.20E-06 kg
[E122]	Chloramine[air_high population density]	1.80E-11 kg
[E123]	Ethene[air_high population density]	0.000179 kg
[E124]	Formaldehyde[air_high population density]	2.58E-05 kg
[E125]	Propylene oxide[air_high population density]	3.89E-06 kg
[E126]	2-Aminopropanol[water_river]	4.74E-12 kg
[E127]	Acetone[water_river]	1.58E-09 kg
[E128]	Chloroacetyl chloride[water_river]	6.31E-12 kg
[E129]	Chloramine[water_river]	1.63E-10 kg
[E130]	Formaldehyde[water_river]	8.70E-08 kg
[E131]	Propylene oxide[water_river]	9.35E-06 kg
[E132]	o-Nitrotoluene[air_high population density]	2.91E-12 kg
[E133]	2-Nitrobenzoic acid[air_high population density]	3.37E-12 kg
[E134]	Methyl acetate[air_high population density]	7.80E-13 kg
[E135]	Isopropylamine[air_high population density]	2.73E-12 kg
[E136]	2-Propanol[air_high population density]	3.55E-06 kg
[E137]	2-Methyl-1-propanol[air_high population density]	9.83E-12 kg
[E138]	Ethylamine[air_high population density]	8.45E-12 kg
[E139]	Chloroform[air_high population density]	1.33E-08 kg
[E140]	Butene[air_high population density]	8.52E-05 kg
[E141]	Anthranilic acid[air_high population density]	2.46E-12 kg
[E142]	Ethyne[air_high population density]	5.55E-07 kg
[E143]	Borate[water_river]	9.23E-10 kg
[E144]	Boron[water_river]	1.75E-05 kg
[E145]	Butene[water_river]	1.51E-08 kg
[E146]	Benzene, chloro-[water_river, long-term]	2.19E-11 kg
[E147]	Chloroform[water_river]	1.22E-09 kg
[E148]	Ethylamine[water_river]	2.03E-11 kg
[E149]	2-Methyl-1-propanol[water_river]	2.36E-11 kg

[E68]	t-Butylamine[air_high population density]	1.43E-11 kg
[E69]	Toluene[air_high population density]	0.00471 kg
[E70]	Acetic acid[water_river]	1.87E-06 kg
[E71]	Acetonitrile[water_river]	1.52E-11 kg
[E72]	Carbonate[water_river]	1.55E-05 kg
[E73]	Chloroacetic acid[water_river]	3.21E-07 kg
[E74]	Chlorosulfonic acid[water_river]	5.54E-11 kg
[E75]	o-Dichlorobenzene[water_river]	2.75E-08 kg
[E76]	Dimethylamine[water_river]	1.63E-10 kg
[E77]	Ethanol[water_river]	1.50E-07 kg
[E78]	Fluoride[water_river]	0.000293 kg
[E79]	Formate[water_river]	4.39E-09 kg
[E80]	Methanol[water_river]	4.15E-07 kg
[E81]	Methyl amine[water_river]	7.55E-11 kg
[E82]	Methane, dichloro-, HCC-30[water_river]	3.42E-05 kg
[E83]	Propanol[water_river]	3.23E-11 kg
[E84]	Propene[water_river]	1.34E-05 kg
[E85]	Sulfate[water_river]	0.0291 kg
[E86]	t-Butylamine[water_river]	3.42E-11 kg
[E87]	Toluene[water_river]	0.000288 kg
[E88]	Water, salt, sole[resource_in water]	-0.0386 m3
[E89]	Bromine, 0.0023% in water[resource_in water]	-6.51E-08 kg
[E90]	Iodine, 0.03% in water[resource_in water]	-1.73E-08 kg
[E91]	Toluene, 2-chloro[air_high population density]	2.22E-11 kg
[E92]	Acetaldehyde[air_high population density]	3.33E-06 kg
[E93]	Aniline[air_high population density]	4.48E-11 kg
[E94]	Diethylamine[air_high population density]	2.09E-11 kg
[E95]	Dipropylamine[air_high population density]	1.23E-11 kg
[E96]	Ethyl acetate[air_high population density]	1.75E-05 kg
[E97]	Lactic acid[air_high population density]	9.61E-12 kg
[E98]	Methyl lactate[air_high population density]	1.05E-11 kg
[E99]	Propanal[air_high population density]	4.19E-09 kg
[E100]	Toluene, 2-chloro[water_river]	4.29E-11 kg
[E101]	Acetaldehyde[water_river]	1.24E-07 kg
[E102]	Aniline[water_river]	1.09E-10 kg
[E103]	Bromide[water_river]	5.93E-08 kg
[E104]	Diethylamine[water_river]	5.01E-11 kg
[E105]	Dipropylamine[water_river]	2.94E-11 kg
[E106]	Ethyl acetate[water_river]	6.29E-11 kg
[E107]	Iodide[water_river]	0.000247 kg
[E108]	Lactic acid[water_river]	2.31E-11 kg
[E109]	Sulfide[water_river]	2.47E-06 kg
[E110]	Phenol, 2,4-dichloro[air_high population density]	7.27E-12 kg
[E111]	Butanol[air_high population density]	3.84E-12 kg
[E112]	Ethylene oxide[air_high population density]	1.02E-07 kg
[E113]	Phenol[air_high population density]	2.82E-07 kg
[E114]	Propane[air_high population density]	0.0036 kg
[E115]	Propionic acid[air_high population density]	5.39E-06 kg
[E116]	Butanol[water_river]	6.36E-08 kg
[E117]	Ethylene oxide[water_river]	1.19E-08 kg
[E118]	Phenol[water_river]	0.000202 kg
[E119]	Propionic acid[water_river]	2.79E-11 kg
[E120]	2-Aminopropanol[air_high population density]	1.80E-12 kg
[E121]	Acetone[air_high population density]	7.55E-06 kg
[E122]	Chloramine[air_high population density]	1.51E-11 kg
[E123]	Ethene[air_high population density]	0.000168 kg
[E124]	Formaldehyde[air_high population density]	2.65E-05 kg
[E125]	Propylene oxide[air_high population density]	3.62E-06 kg
[E126]	2-Aminopropanol[water_river]	4.52E-12 kg
[E127]	Acetone[water_river]	1.51E-09 kg
[E128]	Chloroacetyl chloride[water_river]	6.03E-12 kg
[E129]	Chloramine[water_river]	1.37E-10 kg
[E130]	Formaldehyde[water_river]	4.90E-08 kg
[E131]	Propylene oxide[water_river]	8.70E-06 kg
[E132]	o-Nitrotoluene[air_high population density]	2.78E-12 kg
[E133]	2-Nitrobenzoic acid[air_high population density]	3.22E-12 kg
[E134]	Methyl acetate[air_high population density]	7.46E-13 kg
[E135]	Isopropylamine[air_high population density]	2.58E-12 kg
[E136]	2-Propanol[air_high population density]	3.77E-06 kg
[E137]	2-Methyl-1-propanol[air_high population density]	8.34E-12 kg
[E138]	Ethylamine[air_high population density]	7.47E-12 kg
[E139]	Chloroform[air_high population density]	1.31E-08 kg
[E140]	Butene[air_high population density]	7.99E-05 kg
[E141]	Anthranilic acid[air_high population density]	2.35E-12 kg
[E142]	Ethyne[air_high population density]	5.11E-07 kg
[E143]	Borate[water_river]	7.72E-10 kg
[E144]	Boron[water_river]	1.69E-05 kg
[E145]	Butene[water_river]	1.63E-08 kg
[E146]	Benzene, chloro-[water_river, long-term]	1.85E-11 kg
[E147]	Chloroform[water_river]	1.30E-09 kg
[E148]	Ethylamine[water_river]	1.79E-11 kg
[E149]	2-Methyl-1-propanol[water_river]	2.00E-11 kg

[E68]	t-Butylamine[air_high population density]	1.41E-11 kg
[E69]	Toluene[air_high population density]	0.00468 kg
[E70]	Acetic acid[water_river]	1.73E-06 kg
[E71]	Acetonitrile[water_river]	1.51E-11 kg
[E72]	Carbonate[water_river]	1.40E-05 kg
[E73]	Chloroacetic acid[water_river]	3.18E-07 kg
[E74]	Chlorosulfonic acid[water_river]	5.49E-11 kg
[E75]	o-Dichlorobenzene[water_river]	2.43E-08 kg
[E76]	Dimethylamine[water_river]	1.62E-10 kg
[E77]	Ethanol[water_river]	1.33E-07 kg
[E78]	Fluoride[water_river]	0.000237 kg
[E79]	Formate[water_river]	4.36E-09 kg
[E80]	Methanol[water_river]	3.67E-07 kg
[E81]	Methyl amine[water_river]	6.94E-11 kg
[E82]	Methane, dichloro-, HCC-30[water_river]	3.41E-05 kg
[E83]	Propanol[water_river]	3.15E-11 kg
[E84]	Propene[water_river]	1.28E-05 kg
[E85]	Sulfate[water_river]	0.0127 kg
[E86]	t-Butylamine[water_river]	3.39E-11 kg
[E87]	Toluene[water_river]	0.000287 kg
[E88]	Water, salt, sole[resource_in water]	-0.0384 m3
[E89]	Bromine, 0.0023% in water[resource_in water]	-6.28E-08 kg
[E90]	Iodine, 0.03% in water[resource_in water]	-1.68E-08 kg
[E91]	Toluene, 2-chloro[air_high population density]	2.18E-11 kg
[E92]	Acetaldehyde[air_high population density]	2.91E-06 kg
[E93]	Aniline[air_high population density]	4.39E-11 kg
[E94]	Diethylamine[air_high population density]	2.05E-11 kg
[E95]	Dipropylamine[air_high population density]	1.20E-11 kg
[E96]	Ethyl acetate[air_high population density]	1.55E-05 kg
[E97]	Lactic acid[air_high population density]	9.41E-12 kg
[E98]	Methyl lactate[air_high population density]	1.03E-11 kg
[E99]	Propanal[air_high population density]	4.07E-09 kg
[E100]	Toluene, 2-chloro[water_river]	4.21E-11 kg
[E101]	Acetaldehyde[water_river]	1.10E-07 kg
[E102]	Aniline[water_river]	1.07E-10 kg
[E103]	Bromide[water_river]	5.74E-08 kg
[E104]	Diethylamine[water_river]	4.91E-11 kg
[E105]	Dipropylamine[water_river]	2.88E-11 kg
[E106]	Ethyl acetate[water_river]	6.06E-11 kg
[E107]	Iodide[water_river]	0.000246 kg
[E108]	Lactic acid[water_river]	2.26E-11 kg
[E109]	Sulfide[water_river]	2.39E-06 kg
[E110]	Phenol, 2,4-dichloro[air_high population density]	7.21E-12 kg
[E111]	Butanol[air_high population density]	3.74E-12 kg
[E112]	Ethylene oxide[air_high population density]	9.32E-08 kg
[E113]	Phenol[air_high population density]	2.32E-07 kg
[E114]	Propane[air_high population density]	0.00359 kg
[E115]	Propionic acid[air_high population density]	5.48E-06 kg
[E116]	Butanol[water_river]	5.62E-08 kg
[E117]	Ethylene oxide[water_river]	1.06E-08 kg
[E118]	Phenol[water_river]	0.000201 kg
[E119]	Propionic acid[water_river]	2.77E-11 kg
[E120]	2-Aminopropanol[air_high population density]	1.78E-12 kg
[E121]	Acetone[air_high population density]	6.61E-06 kg
[E122]	Chloramine[air_high population density]	1.44E-11 kg
[E123]	Ethene[air_high population density]	0.000166 kg
[E124]	Formaldehyde[air_high population density]	2.48E-05 kg
[E125]	Propylene oxide[air_high population density]	3.59E-06 kg
[E126]	2-Aminopropanol[water_river]	4.48E-12 kg
[E127]	Acetone[water_river]	1.50E-09 kg
[E128]	Chloroacetyl chloride[water_river]	5.98E-12 kg
[E129]	Chloramine[water_river]	1.31E-10 kg
[E130]	Formaldehyde[water_river]	4.17E-08 kg
[E131]	Propylene oxide[water_river]	8.64E-06 kg
[E132]	o-Nitrotoluene[air_high population density]	2.76E-12 kg
[E133]	2-Nitrobenzoic acid[air_high population density]	3.20E-12 kg
[E134]	Methyl acetate[air_high population density]	7.40E-13 kg
[E135]	Isopropylamine[air_high population density]	2.55E-12 kg
[E136]	2-Propanol[air_high population density]	3.33E-06 kg
[E137]	2-Methyl-1-propanol[air_high population density]	8.00E-12 kg
[E138]	Ethylamine[air_high population density]	7.23E-12 kg
[E139]	Chloroform[air_high population density]	1.17E-08 kg
[E140]	Butene[air_high population density]	7.96E-05 kg
[E141]	Anthranilic acid[air_high population density]	2.33E-12 kg
[E142]	Ethyne[air_high population density]	3.98E-07 kg
[E143]	Borate[water_river]	7.37E-10 kg
[E144]	Boron[water_river]	1.61E-05 kg
[E145]	Butene[water_river]	1.41E-08 kg
[E146]	Benzene, chloro-[water_river, long-term]	1.77E-11 kg
[E147]	Chloroform[water_river]	1.15E-09 kg
[E148]	Ethylamine[water_river]	1.73E-11 kg
[E149]	2-Methyl-1-propanol[water_river]	1.92E-11 kg

Appendix C: Results of inventory analysis

[E150]	2-Propanol[water_river]	1.51E-11 kg	1.43E-11 kg	1.41E-11 kg
[E151]	Isopropylamine[water_river]	6.55E-12 kg	6.20E-12 kg	6.12E-12 kg
[E152]	Methyl acetate[water_river]	1.87E-12 kg	1.79E-12 kg	1.78E-12 kg
[E153]	Phosphorus[water_river]	1.35E-05 kg	1.33E-05 kg	1.23E-05 kg
[E154]	1-Pentanol[air_high population density]	4.02E-12 kg	3.24E-12 kg	3.06E-12 kg
[E155]	Benzene[air_high population density]	0.0108 kg	0.0108 kg	0.0108 kg
[E156]	Formamide[air_high population density]	7.36E-12 kg	5.93E-12 kg	5.60E-12 kg
[E157]	Formic acid[air_high population density]	2.06E-08 kg	2.19E-08 kg	1.94E-08 kg
[E158]	1-Pentene[air_high population density]	3.04E-12 kg	2.45E-12 kg	2.31E-12 kg
[E159]	1-Pentanol[water_river]	9.66E-12 kg	7.78E-12 kg	7.35E-12 kg
[E160]	Acetyl chloride[water_river]	7.59E-12 kg	6.12E-12 kg	5.77E-12 kg
[E161]	Benzene[water_river]	0.000178 kg	0.000167 kg	0.000165 kg
[E162]	Formamide[water_river]	1.77E-11 kg	1.42E-11 kg	1.34E-11 kg
[E163]	Formic acid[water_river]	5.13E-12 kg	4.13E-12 kg	3.90E-12 kg
[E164]	Lithium, ion[water_river]	3.37E-10 kg	2.72E-10 kg	2.56E-10 kg
[E165]	1-Pentene[water_river]	7.30E-12 kg	5.88E-12 kg	5.55E-12 kg
[E166]	Propanal[water_river]	1.40E-11 kg	1.13E-11 kg	1.06E-11 kg
[E167]	Silicon[water_river]	0.000234 kg	0.000242 kg	0.000196 kg
[E168]	Ethane, 1,2-dichloro-[air_high population density]	7.61E-07 kg	5.87E-07 kg	5.25E-07 kg
[E169]	Trimethylamine[air_high population density]	1.38E-12 kg	1.32E-12 kg	1.31E-12 kg
[E170]	Ethane, 1,2-dichloro-[water_river]	4.55E-08 kg	4.61E-08 kg	4.00E-08 kg
[E171]	Trimethylamine[water_river]	3.32E-12 kg	3.17E-12 kg	3.15E-12 kg
[E172]	Carbon disulfide[air_high population density]	2.14E-10 kg	1.64E-10 kg	1.55E-10 kg
[E173]	Ethylene diamine[air_high population density]	2.25E-10 kg	1.99E-10 kg	1.95E-10 kg
[E174]	Carbon disulfide[water_river]	3.46E-10 kg	2.61E-10 kg	2.40E-10 kg
[E175]	Ethylene diamine[water_river]	5.45E-10 kg	4.81E-10 kg	4.71E-10 kg
[E176]	Manganese[water_river]	0.000445 kg	0.000113 kg	0.000111 kg
[E177]	m-Xylene[air_high population density]	2.05E-07 kg	2.26E-07 kg	1.79E-07 kg
[E178]	m-Xylene[water_river]	1.83E-11 kg	1.46E-11 kg	1.38E-11 kg
[E179]	Aluminium[water_river]	0.000125 kg	1.06E-04 kg	0.000122 kg
[E180]	Propylamine[air_high population density]	2.33E-12 kg	1.88E-12 kg	1.77E-12 kg
[E181]	Butadiene[air_high population density]	2.59E-12 kg	2.09E-12 kg	1.97E-12 kg
[E182]	Ethene[water_river]	7.44E-06 kg	6.97E-06 kg	6.47E-06 kg
[E183]	Propylamine[water_river]	5.59E-12 kg	4.51E-12 kg	4.25E-12 kg
[E184]	Urea[water_river]	1.78E-11 kg	1.46E-11 kg	1.39E-11 kg
[E185]	Occupation, arable, non-irrigated[resource_land]	-0.00756 m2a	-0.00718 m2a	-0.00711 m2a
[E186]	Transformation, from arable, non-irrigated[resource_land]	-0.014 m2	-0.0133 m2	-0.0131 m2
[E187]	Transformation, to arable, non-irrigated[resource_land]	-0.014 m2	-0.0133 m2	-0.0132 m2
[E188]	Asulam[soil_agricultural]	4.66E-20 kg	-1.09E-18 kg	-6.91E-20 kg
[E189]	Dinitrogen monoxide[air_low population density]	0.000281 kg	0.000282 kg	0.000263 kg
[E190]	Nitrate[water_ground-]	0.000711 kg	0.000362 kg	0.000336 kg
[E191]	Phosphate[water_ground-]	0.00317 kg	0.00346 kg	0.00281 kg
[E192]	Nitrogen oxides[air_low population density]	0.0933 kg	0.0891 kg	0.087 kg
[E193]	Cadmium[soil_agricultural]	8.49E-09 kg	9.38E-09 kg	7.81E-09 kg
[E194]	Chromium[soil_agricultural]	7.42E-08 kg	9.88E-08 kg	6.83E-08 kg
[E195]	Copper[soil_agricultural]	1.24E-07 kg	2.28E-07 kg	1.20E-07 kg
[E196]	Lead[soil_agricultural]	4.16E-08 kg	6.96E-08 kg	3.95E-08 kg
[E197]	Mercury[soil_agricultural]	4.21E-10 kg	9.01E-10 kg	4.24E-10 kg
[E198]	Nickel[soil_agricultural]	4.99E-08 kg	6.11E-08 kg	4.65E-08 kg
[E199]	Zinc[soil_agricultural]	8.69E-07 kg	1.15E-06 kg	8.14E-07 kg
[E200]	Cadmium, ion[water_ground-]	3.34E-05 kg	4.21E-08 kg	3.60E-08 kg
[E201]	Chromium, ion[water_ground-]	1.10E-06 kg	1.47E-08 kg	1.44E-08 kg
[E202]	Copper, ion[water_ground-]	3.90E-06 kg	2.88E-07 kg	2.42E-07 kg
[E203]	Lead[water_ground-]	6.44E-06 kg	2.01E-08 kg	1.72E-08 kg
[E204]	Mercury[water_ground-]	1.39E-07 kg	4.17E-09 kg	3.32E-09 kg
[E205]	Zinc, ion[water_ground-]	6.41E-05 kg	2.44E-06 kg	2.04E-06 kg
[E206]	Carbon dioxide, in air[resource_in air]	-0.298 kg	-0.317 kg	-0.255 kg
[E207]	Energy, gross calorific value, in biomass[resource_biotic]	-2.85 MJ	-2.97 MJ	-2.39 MJ
[E209]	Ammonia[air_low population density]	0.000208 kg	0.000199 kg	0.000193 kg
[E210]	Atrazine[soil_agricultural]	6.19E-11 kg	6.59E-11 kg	5.82E-11 kg
[E211]	Metolachlor[soil_agricultural]	1.62E-06 kg	1.55E-06 kg	1.54E-06 kg
[E212]	Glyphosate[soil_agricultural]	3.94E-06 kg	3.83E-06 kg	3.82E-06 kg
[E213]	Chlorothalonil[soil_agricultural]	7.83E-08 kg	5.86E-08 kg	5.39E-08 kg
[E214]	Fenpiclonil[soil_agricultural]	4.08E-09 kg	3.26E-09 kg	3.07E-09 kg
[E215]	Mancozeb[soil_agricultural]	1.02E-07 kg	7.61E-08 kg	7.00E-08 kg
[E216]	Metribuzin[soil_agricultural]	3.58E-09 kg	2.68E-09 kg	2.47E-09 kg
[E217]	Orbencarb[soil_agricultural]	1.93E-08 kg	1.45E-08 kg	1.33E-08 kg
[E218]	Teflubenzuron[soil_agricultural]	2.39E-10 kg	1.79E-10 kg	1.64E-10 kg
[E219]	NMVOC, non-methane volatile organic compounds, unspecified origin[air_low population density]	0.112 kg	0.104 kg	0.104 kg
[E220]	Carbon monoxide, fossil[air_low population density]	0.0246 kg	0.0248 kg	0.023 kg
[E221]	Sulfur dioxide[air_low population density]	0.14 kg	0.136 kg	0.131 kg
[E222]	Methane, fossil[air_low population density]	4.85 kg	0.248 kg	0.247 kg
[E223]	Benzene[air_low population density]	3.90E-05 kg	4.14E-05 kg	3.53E-05 kg
[E224]	Particulates, < 2.5 um[air_low population density]	0.00709 kg	0.00682 kg	0.00644 kg
[E225]	Cadmium[air_low population density]	1.62E-06 kg	7.28E-07 kg	6.30E-07 kg
[E226]	Chromium[air_low population density]	2.62E-05 kg	1.70E-05 kg	1.49E-05 kg
[E227]	Copper[air_low population density]	9.20E-06 kg	8.71E-06 kg	7.68E-06 kg
[E228]	Nickel[air_low population density]	1.42E-05 kg	1.35E-05 kg	1.27E-05 kg
[E229]	Zinc[air_low population density]	1.51E-05 kg	1.37E-05 kg	1.26E-05 kg
[E230]	Benzo(a)pyrene[air_low population density]	1.26E-07 kg	1.39E-07 kg	1.12E-07 kg
[E231]	PAH, polycyclic aromatic hydrocarbons[air_low population density]	1.15E-06 kg	1.10E-06 kg	1.07E-06 kg
[E232]	Selenium[air_low population density]	8.18E-07 kg	8.79E-07 kg	7.33E-07 kg
[E233]	Lead[air_low population density]	9.56E-06 kg	9.08E-06 kg	8.14E-06 kg
[E234]	Transformation, from pasture and meadow, intensive[resource_land]	-1.14E-05 m2	-1.08E-05 m2	-1.07E-05 m2
[E235]	Cyproconazole[soil_agricultural]	1.23E-22 kg	-4.54E-23 kg	8.17E-23 kg

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[E236]	Cyprodinil[soil_agricultural]	4.87E-22 kg	-1.80E-22 kg	3.24E-22 kg
[E237]	Metaldehyde[soil_agricultural]	1.02E-09 kg	9.71E-10 kg	9.62E-10 kg
[E238]	Chlorotoluron[soil_agricultural]	3.67E-20 kg	-1.36E-20 kg	2.44E-20 kg
[E239]	Isoproturon[soil_agricultural]	1.09E-19 kg	-4.03E-20 kg	7.25E-20 kg
[E240]	Pendimethalin[soil_agricultural]	2.81E-20 kg	-1.04E-20 kg	1.87E-20 kg
[E241]	Fenpropimorph[soil_agricultural]	2.38E-20 kg	-8.79E-21 kg	1.58E-20 kg
[E242]	Ethephon[soil_agricultural]	7.21E-21 kg	-2.66E-21 kg	4.79E-21 kg
[E243]	Bentazone[soil_agricultural]	1.48E-08 kg	1.42E-08 kg	1.41E-08 kg
[E248]	Carbon, in organic matter, in soil[resource_in ground]	-6.74E-05 kg	-6.28E-05 kg	-6.23E-05 kg
[E249]	Transformation, from forest, intensive, clear-cutting[resource_land]	-4.18E-05 m2	-3.90E-05 m2	-3.87E-05 m2
[E250]	Transformation, to forest, intensive, short-cycle[resource_land]	-4.18E-05 m2	-3.90E-05 m2	-3.87E-05 m2
[E251]	Occupation, forest, intensive, short-cycle[resource_land]	-0.00117 m2a	-0.00109 m2a	-0.00108 m2a
[E252]	Carbon dioxide, land transformation[air_low population density]	5 kg	5 kg	5.25 kg
[E253]	Phosphorus[water_ground-]	7.33E-09 kg	6.83E-09 kg	6.78E-09 kg
[E254]	2,4-D[soil_agricultural]	1.53E-08 kg	1.42E-08 kg	1.41E-08 kg
[E255]	Carbofuran[soil_agricultural]	5.33E-08 kg	4.97E-08 kg	4.93E-08 kg
[E256]	Cypermethrin[soil_agricultural]	7.65E-09 kg	7.13E-09 kg	7.07E-09 kg
[E257]	Thiram[soil_agricultural]	1.73E-10 kg	1.61E-10 kg	1.60E-10 kg
[E258]	Benomyl[soil_agricultural]	9.73E-11 kg	9.06E-11 kg	9.00E-11 kg
[E264]	Transformation, from forest, extensive[resource_land]	-0.00191 m2	-0.00206 m2	-0.00164 m2
[E265]	Transformation, to permanent crop, fruit, intensive[resource_land]	-2.39E-05 m2	-2.22E-05 m2	-2.21E-05 m2
[E266]	Occupation, permanent crop, fruit, intensive[resource_land]	-0.0017 m2a	-0.00158 m2a	-0.00157 m2a
[E267]	Aclonifen[soil_agricultural]	2.90E-08 kg	2.78E-08 kg	2.76E-08 kg
[E268]	Carbetamide[soil_agricultural]	5.32E-09 kg	5.08E-09 kg	5.03E-09 kg
[E269]	Pirimicarb[soil_agricultural]	1.40E-09 kg	1.34E-09 kg	1.33E-09 kg
[E270]	Tebutam[soil_agricultural]	4.29E-09 kg	4.07E-09 kg	4.03E-09 kg
[E271]	Trifluralin[soil_agricultural]	-3.63E-24 kg	-2.74E-24 kg	-2.91E-24 kg
[E272]	Napropamide[soil_agricultural]	1.81E-09 kg	1.72E-09 kg	1.70E-09 kg
[E273]	Difenoconazole[soil_agricultural]	1.18E-21 kg	-4.36E-22 kg	7.85E-22 kg
[E274]	Linuron[soil_agricultural]	2.24E-07 kg	2.14E-07 kg	2.12E-07 kg
[E276]	Ioxynil[soil_agricultural]	1.22E-20 kg	-4.52E-21 kg	8.13E-21 kg
[E277]	Mecoprop-P[soil_agricultural]	2.06E-20 kg	-7.62E-21 kg	1.37E-20 kg
[E278]	Tebuconazole[soil_agricultural]	5.50E-21 kg	-2.03E-21 kg	3.66E-21 kg
[E279]	Chlormequat[soil_agricultural]	7.90E-21 kg	-2.92E-21 kg	5.26E-21 kg
[E280]	Water, unspecified natural origin[resource_in water]	-0.381 m3	-0.205 m3	-0.193 m3
[E281]	COD, Chemical Oxygen Demand[water_unspecified]	0.000246 kg	0.000218 kg	0.000209 kg
[E282]	Heat, waste[air_unspecified]	183 MJ	104 MJ	99.4 MJ
[E283]	Sodium, ion[water_unspecified]	0.107 kg	0.104 kg	0.104 kg
[E284]	Suspended solids, unspecified[water_unspecified]	0.000265 kg	0.000235 kg	0.000225 kg
[E285]	BOD5, Biological Oxygen Demand[water_unspecified]	0.000242 kg	0.000214 kg	0.000206 kg
[E286]	DOC, Dissolved Organic Carbon[water_unspecified]	0.0462 kg	3.22E-05 kg	3.11E-05 kg
[E287]	TOC, Total Organic Carbon[water_unspecified]	3.59E-05 kg	3.22E-05 kg	3.11E-05 kg
[E288]	Nitrogen[water_river]	0.00166 kg	0.000174 kg	0.000154 kg
[E289]	Arsenic[air_high population density]	8.74E-07 kg	8.28E-07 kg	8.01E-07 kg
[E290]	Benzo(a)pyrene[air_high population density]	1.67E-09 kg	2.19E-09 kg	1.51E-09 kg
[E291]	Calcium[air_high population density]	1.97E-05 kg	0.00013 kg	1.74E-05 kg
[E292]	Cadmium[air_high population density]	2.56E-06 kg	2.53E-06 kg	2.45E-06 kg
[E293]	Chromium[air_high population density]	3.63E-06 kg	3.61E-06 kg	3.56E-06 kg
[E294]	Chromium VI[air_high population density]	1.32E-08 kg	1.30E-08 kg	1.18E-08 kg
[E295]	Cobalt[air_high population density]	2.01E-06 kg	1.98E-06 kg	1.89E-06 kg
[E296]	Copper[air_high population density]	9.52E-05 kg	9.52E-05 kg	9.48E-05 kg
[E297]	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin[air_high population density]	2.35E-12 kg	3.18E-10 kg	1.48E-12 kg
[E298]	Hydrocarbons, aliphatic, alkanes, unspecified[air_high population density]	0.000107 kg	1.02E-04 kg	9.90E-05 kg
[E299]	Hydrocarbons, aliphatic, unsaturated[air_high population density]	6.59E-06 kg	7.11E-06 kg	5.69E-06 kg
[E300]	Hydrocarbons, aromatic[air_high population density]	2.99E-05 kg	9.57E-06 kg	9.31E-06 kg
[E301]	Iron[air_high population density]	1.50E-05 kg	1.65E-05 kg	1.32E-05 kg
[E302]	Lead[air_high population density]	5.50E-06 kg	5.34E-06 kg	5.19E-06 kg
[E303]	Mercury[air_high population density]	2.12E-07 kg	1.11E-06 kg	2.53E-07 kg
[E304]	Molybdenum[air_high population density]	9.50E-07 kg	9.20E-07 kg	8.95E-07 kg
[E305]	Nickel[air_high population density]	2.73E-05 kg	2.66E-05 kg	2.58E-05 kg
[E306]	PAH, polycyclic aromatic hydrocarbons[air_high population density]	2.74E-06 kg	2.78E-06 kg	2.82E-06 kg
[E307]	Selenium[air_high population density]	1.33E-06 kg	1.30E-06 kg	1.28E-06 kg
[E308]	Sodium[air_high population density]	5.08E-05 kg	0.000604 kg	4.77E-05 kg
[E309]	Vanadium[air_high population density]	5.84E-05 kg	6.45E-05 kg	5.46E-05 kg
[E310]	Zinc[air_high population density]	0.000521 kg	0.000521 kg	0.00052 kg
[E311]	Butane[air_high population density]	0.00395 kg	0.00373 kg	0.00372 kg
[E312]	Pentane[air_high population density]	0.00501 kg	0.00472 kg	0.00471 kg
[E313]	Barite, 15% in crude ore, in ground[resource_in ground]	-0.242 kg	-0.235 kg	-0.23 kg
[E314]	Particulates, > 10 um[air_low population density]	0.0123 kg	0.012 kg	0.0107 kg
[E315]	Sulfate[air_high population density]	0.00022 kg	0.00023 kg	0.000201 kg
[E316]	Water, well, in ground[resource_in water]	-0.0256 m3	-0.0225 m3	-0.0284 m3
[E317]	Colemanite, in ground[resource_in ground]	-0.00043 kg	-5.84E-05 kg	-5.09E-05 kg
[E318]	Occupation, mineral extraction site[resource_land]	-0.0594 m2a	-0.0235 m2a	-0.0216 m2a
[E319]	Transformation, to mineral extraction site[resource_land]	-0.0627 m2	-0.0564 m2	-0.0561 m2

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[E320]	Transformation, from forest[resource_land]	-0.0727 m2
[E321]	Solids, inorganic[water_river]	0.000919 kg
[E322]	Monoethanolamine[air_high population density]	5.31E-07 kg
[E323]	Sodium chlorate[air_high population density]	5.03E-08 kg
[E324]	Cyanide[water_river]	8.78E-06 kg
[E325]	Chlorate[water_river]	4.54E-05 kg
[E326]	Bromate[water_river]	5.58E-06 kg
[E327]	Chlorinated solvents, unspecified[water_river]	3.59E-08 kg
[E328]	Methane, tetrachloro-, R-10[air_high population density]	4.35E-08 kg
[E329]	Sodium dichromate[air_high population density]	4.88E-08 kg
[E330]	Dichromate[water_river]	1.80E-07 kg
[E331]	DOC, Dissolved Organic Carbon[water_river]	0.164 kg
[E332]	TOC, Total Organic Carbon[water_river]	0.165 kg
[E333]	Ammonium carbonate[air_high population density]	9.62E-09 kg
[E334]	Hydrogen fluoride[air_unspecified]	2.50E-05 kg
[E335]	Fluorspar, 92%, in ground[resource_in ground]	-0.00419 kg
[E336]	Particulates, < 2.5 um[air_unspecified]	0.00673 kg
[E337]	Particulates, > 2.5 um, and < 10um[air_unspecified]	0.000867 kg
[E338]	Particulates, > 10 um[air_unspecified]	0.00114 kg
[E339]	Hydrogen fluoride[air_low population density]	0.000138 kg
[E340]	Particulates, > 2.5 um, and < 10um[air_low population density]	0.00559 kg
[E341]	Uranium-238[air_low population density]	0.000678 kBq
[E342]	Thorium-228[air_low population density]	3.89E-05 kBq
[E343]	Radium-226[air_low population density]	0.0017 kBq
[E344]	Radon-222[air_low population density]	139 kBq
[E345]	Lead-210[air_low population density]	0.00102 kBq
[E346]	Polonium-210[air_low population density]	0.00175 kBq
[E347]	Potassium-40[air_low population density]	0.000191 kBq
[E348]	Fluoride[water_ocean]	9.13E-05 kg
[E349]	Calcium, ion[water_ocean]	0.0266 kg
[E350]	Sulfate[water_ocean]	0.00508 kg
[E351]	Phosphate[water_ocean]	2.77E-05 kg
[E352]	Cadmium, ion[water_ocean]	2.31E-07 kg
[E353]	Lead[water_ocean]	6.28E-06 kg
[E354]	Arsenic, ion[water_ocean]	6.02E-07 kg
[E355]	Chromium, ion[water_ocean]	3.97E-06 kg
[E356]	Copper, ion[water_ocean]	1.49E-06 kg
[E357]	Manganese[water_ocean]	3.69E-05 kg
[E358]	Nickel, ion[water_ocean]	4.24E-07 kg
[E359]	Zinc, ion[water_ocean]	0.00057 kg
[E360]	Uranium-238[water_ocean]	0.000842 kBq
[E361]	Thorium-228[water_ocean]	0.167 kBq
[E362]	Radium-226[water_ocean]	0.0687 kBq
[E363]	Lead-210[water_ocean]	0.00164 kBq
[E364]	Polonium-210[water_ocean]	0.00251 kBq
[E365]	Potassium-40[water_ocean]	0.000198 kBq
[E366]	Occupation, industrial area, vegetation[resource_land]	-0.0243 m2a
[E367]	Transformation, to industrial area, vegetation[resource_land]	-0.00059 m2
[E368]	Transformation, from industrial area, built up[resource_land]	-2.02E-07 m2
[E369]	Transformation, from industrial area, vegetation[resource_land]	-3.45E-07 m2
[E370]	Transformation, to pasture and meadow[resource_land]	-4.94E-05 m2
[E371]	Transformation, to unknown[resource_land]	-8.36E-05 m2
[E372]	Silicon tetrafluoride[air_low population density]	4.29E-09 kg
[E373]	Fluoride[water_ground-]	1.55E-05 kg
[E374]	Calcium, ion[water_ground-]	0.00187 kg
[E375]	Sulfate[water_ground-]	0.0331 kg
[E376]	Arsenic, ion[water_ground-]	4.33E-06 kg
[E377]	Manganese[water_ground-]	0.00025 kg
[E378]	Nickel, ion[water_ground-]	4.22E-06 kg
[E379]	Uranium-238[water_ground-]	7.03E-07 kBq
[E380]	Thorium-228[water_ground-]	1.68E-08 kBq
[E381]	Radium-226[water_ground-]	1.54E-06 kBq
[E382]	Lead-210[water_ground-]	1.37E-06 kBq
[E383]	Polonium-210[water_ground-]	2.08E-06 kBq
[E384]	Potassium-40[water_ground-]	1.66E-07 kBq
[E385]	Metamorphous rock, graphite containing, in ground[resource_in ground]	-3.41E-05 kg
[E386]	Sulfur dioxide[air_unspecified]	0.00361 kg
[E387]	BOD5, Biological Oxygen Demand[water_river]	0.488 kg
[E388]	COD, Chemical Oxygen Demand[water_river]	0.552 kg
[E389]	Hydrocarbons, aromatic[water_river]	0.00139 kg
[E390]	Suspended solids, unspecified[water_river]	0.00349 kg
[E391]	Hydrogen peroxide[water_river]	2.23E-07 kg
[E392]	Oil, crude, in ground[resource_in ground]	-62.4 kg
[E393]	Gas, natural, in ground[resource_in ground]	-14.4 Nm3
[E394]	Coal, hard, unspecified, in ground[resource_in ground]	-2.39 kg

[E320]	Transformation, from forest[resource_land]	-0.0698 m2
[E321]	Solids, inorganic[water_river]	0.00254 kg
[E322]	Monoethanolamine[air_high population density]	5.37E-07 kg
[E323]	Sodium chlorate[air_high population density]	5.42E-08 kg
[E324]	Cyanide[water_river]	8.35E-06 kg
[E325]	Chlorate[water_river]	0.00159 kg
[E326]	Bromate[water_river]	0.000207 kg
[E327]	Chlorinated solvents, unspecified[water_river]	4.71E-07 kg
[E328]	Methane, tetrachloro-, R-10[air_high population density]	6.86E-08 kg
[E329]	Sodium dichromate[air_high population density]	5.02E-08 kg
[E330]	Dichromate[water_river]	1.85E-07 kg
[E331]	DOC, Dissolved Organic Carbon[water_river]	0.137 kg
[E332]	TOC, Total Organic Carbon[water_river]	0.138 kg
[E333]	Ammonium carbonate[air_high population density]	8.32E-09 kg
[E334]	Hydrogen fluoride[air_unspecified]	2.32E-05 kg
[E335]	Fluorspar, 92%, in ground[resource_in ground]	-0.00454 kg
[E336]	Particulates, < 2.5 um[air_unspecified]	0.00201 kg
[E337]	Particulates, > 2.5 um, and < 10um[air_unspecified]	0.000514 kg
[E338]	Particulates, > 10 um[air_unspecified]	0.000723 kg
[E339]	Hydrogen fluoride[air_low population density]	9.56E-05 kg
[E340]	Particulates, > 2.5 um, and < 10um[air_low population density]	0.00504 kg
[E341]	Uranium-238[air_low population density]	0.00067 kBq
[E342]	Thorium-228[air_low population density]	4.51E-05 kBq
[E343]	Radium-226[air_low population density]	0.00163 kBq
[E344]	Radon-222[air_low population density]	131 kBq
[E345]	Lead-210[air_low population density]	0.00111 kBq
[E346]	Polonium-210[air_low population density]	0.00193 kBq
[E347]	Potassium-40[air_low population density]	0.000222 kBq
[E348]	Fluoride[water_ocean]	8.83E-05 kg
[E349]	Calcium, ion[water_ocean]	0.0255 kg
[E350]	Sulfate[water_ocean]	0.0051 kg
[E351]	Phosphate[water_ocean]	3.00E-05 kg
[E352]	Cadmium, ion[water_ocean]	2.24E-07 kg
[E353]	Lead[water_ocean]	6.03E-06 kg
[E354]	Arsenic, ion[water_ocean]	5.84E-07 kg
[E355]	Chromium, ion[water_ocean]	3.81E-06 kg
[E356]	Copper, ion[water_ocean]	1.49E-06 kg
[E357]	Manganese[water_ocean]	3.53E-05 kg
[E358]	Nickel, ion[water_ocean]	4.16E-07 kg
[E359]	Zinc, ion[water_ocean]	0.000551 kg
[E360]	Uranium-238[water_ocean]	0.000913 kBq
[E361]	Thorium-228[water_ocean]	0.16 kBq
[E362]	Radium-226[water_ocean]	0.0661 kBq
[E363]	Lead-210[water_ocean]	0.00178 kBq
[E364]	Polonium-210[water_ocean]	0.00272 kBq
[E365]	Potassium-40[water_ocean]	0.000215 kBq
[E366]	Occupation, industrial area, vegetation[resource_land]	-0.0083 m2a
[E367]	Transformation, to industrial area, vegetation[resource_land]	-0.00022 m2
[E368]	Transformation, from industrial area, built up[resource_land]	-2.20E-07 m2
[E369]	Transformation, from industrial area, vegetation[resource_land]	-3.75E-07 m2
[E370]	Transformation, to pasture and meadow[resource_land]	-5.02E-05 m2
[E371]	Transformation, to unknown[resource_land]	-8.05E-05 m2
[E372]	Silicon tetrafluoride[air_low population density]	4.66E-09 kg
[E373]	Fluoride[water_ground-]	1.38E-05 kg
[E374]	Calcium, ion[water_ground-]	0.00208 kg
[E375]	Sulfate[water_ground-]	0.035 kg
[E376]	Arsenic, ion[water_ground-]	4.10E-06 kg
[E377]	Manganese[water_ground-]	4.05E-05 kg
[E378]	Nickel, ion[water_ground-]	1.57E-06 kg
[E379]	Uranium-238[water_ground-]	7.64E-07 kBq
[E380]	Thorium-228[water_ground-]	1.82E-08 kBq
[E381]	Radium-226[water_ground-]	1.67E-06 kBq
[E382]	Lead-210[water_ground-]	1.49E-06 kBq
[E383]	Polonium-210[water_ground-]	2.26E-06 kBq
[E384]	Potassium-40[water_ground-]	1.80E-07 kBq
[E385]	Metamorphous rock, graphite containing, in ground[resource_in ground]	-3.25E-05 kg
[E386]	Sulfur dioxide[air_unspecified]	0.00228 kg
[E387]	BOD5, Biological Oxygen Demand[water_river]	0.442 kg
[E388]	COD, Chemical Oxygen Demand[water_river]	0.448 kg
[E389]	Hydrocarbons, aromatic[water_river]	0.0013 kg
[E390]	Suspended solids, unspecified[water_river]	0.00322 kg
[E391]	Hydrogen peroxide[water_river]	2.31E-07 kg
[E392]	Oil, crude, in ground[resource_in ground]	-58.4 kg
[E393]	Gas, natural, in ground[resource_in ground]	-14.1 Nm3
[E394]	Coal, hard, unspecified, in ground[resource_in ground]	-2.42 kg

[E320]	Transformation, from forest[resource_land]	-0.0701 m2
[E321]	Solids, inorganic[water_river]	0.000924 kg
[E322]	Monoethanolamine[air_high population density]	4.88E-07 kg
[E323]	Sodium chlorate[air_high population density]	4.69E-08 kg
[E324]	Cyanide[water_river]	7.87E-06 kg
[E325]	Chlorate[water_river]	0.000134 kg
[E326]	Bromate[water_river]	1.72E-05 kg
[E327]	Chlorinated solvents, unspecified[water_river]	5.46E-08 kg
[E328]	Methane, tetrachloro-, R-10[air_high population density]	4.12E-08 kg
[E329]	Sodium dichromate[air_high population density]	3.75E-08 kg
[E330]	Dichromate[water_river]	1.38E-07 kg
[E331]	DOC, Dissolved Organic Carbon[water_river]	0.135 kg
[E332]	TOC, Total Organic Carbon[water_river]	0.136 kg
[E333]	Ammonium carbonate[air_high population density]	7.53E-09 kg
[E334]	Hydrogen fluoride[air_unspecified]	2.20E-05 kg
[E335]	Fluorspar, 92%, in ground[resource_in ground]	-0.00392 kg
[E336]	Particulates, < 2.5 um[air_unspecified]	0.00193 kg
[E337]	Particulates, > 2.5 um, and < 10um[air_unspecified]	0.000478 kg
[E338]	Particulates, > 10 um[air_unspecified]	0.000655 kg
[E339]	Hydrogen fluoride[air_low population density]	7.48E-05 kg
[E340]	Particulates, > 2.5 um, and < 10um[air_low population density]	0.00479 kg
[E341]	Uranium-238[air_low population density]	0.000563 kBq
[E342]	Thorium-228[air_low population density]	3.50E-05 kBq
[E343]	Radium-226[air_low population density]	0.00139 kBq
[E344]	Radon-222[air_low population density]	113 kBq
[E345]	Lead-210[air_low population density]	0.00089 kBq
[E346]	Polonium-210[air_low population density]	0.00154 kBq
[E347]	Potassium-40[air_low population density]	0.000172 kBq
[E348]	Fluoride[water_ocean]	8.70E-05 kg
[E349]	Calcium, ion[water_ocean]	0.0253 kg
[E350]	Sulfate[water_ocean]	0.00482 kg
[E351]	Phosphate[water_ocean]	2.60E-05 kg
[E352]	Cadmium, ion[water_ocean]	2.21E-07 kg
[E353]	Lead[water_ocean]	6.00E-06 kg
[E354]	Arsenic, ion[water_ocean]	5.76E-07 kg
[E355]	Chromium, ion[water_ocean]	3.79E-06 kg
[E356]	Copper, ion[water_ocean]	1.42E-06 kg
[E357]	Manganese[water_ocean]	3.52E-05 kg
[E358]	Nickel, ion[water_ocean]	4.04E-07 kg
[E359]	Zinc, ion[water_ocean]	0.00055 kg
[E360]	Uranium-238[water_ocean]	0.000792 kBq
[E361]	Thorium-228[water_ocean]	0.159 kBq
[E362]	Radium-226[water_ocean]	0.0655 kBq
[E363]	Lead-210[water_ocean]	0.00154 kBq
[E364]	Polonium-210[water_ocean]	0.00236 kBq
[E365]	Potassium-40[water_ocean]	0.000187 kBq
[E366]	Occupation, industrial area, vegetation[resource_land]	-0.00753 m2a
[E367]	Transformation, to industrial area, vegetation[resource_land]	-0.0002 m2
[E368]	Transformation, from industrial area, built up[resource_land]	-1.90E-07 m2
[E369]	Transformation, from industrial area, vegetation[resource_land]	-3.25E-07 m2
[E370]	Transformation, to pasture and meadow[resource_land]	-5.08E-05 m2
[E371]	Transformation, to unknown[resource_land]	-7.33E-05 m2
[E372]	Silicon tetrafluoride[air_low population density]	4.03E-09 kg
[E373]	Fluoride[water_ground-]	1.14E-05 kg
[E374]	Calcium, ion[water_ground-]	0.00167 kg
[E375]	Sulfate[water_ground-]	0.0283 kg
[E376]	Arsenic, ion[water_ground-]	3.18E-06 kg
[E377]	Manganese[water_ground-]	3.25E-05 kg
[E378]	Nickel, ion[water_ground-]	1.26E-06 kg
[E379]	Uranium-238[water_ground-]	6.60E-07 kBq
[E380]	Thorium-228[water_ground-]	1.58E-08 kBq
[E381]	Radium-226[water_ground-]	1.44E-06 kBq
[E382]	Lead-210[water_ground-]	1.29E-06 kBq
[E383]	Polonium-210[water_ground-]	1.96E-06 kBq
[E384]	Potassium-40[water_ground-]	1.56E-07 kBq
[E385]	Metamorphous rock, graphite containing, in ground[resource_in ground]	-3.10E-05 kg
[E386]	Sulfur dioxide[air_unspecified]	0.00215 kg
[E387]	BOD5, Biological Oxygen Demand[water_river]	0.439 kg
[E388]	COD, Chemical Oxygen Demand[water_river]	0.443 kg
[E389]	Hydrocarbons, aromatic[water_river]	0.0013 kg
[E390]	Suspended solids, unspecified[water_river]	0.00316 kg
[E391]	Hydrogen peroxide[water_river]	2.16E-07 kg
[E392]	Oil, crude, in ground[resource_in ground]	-58.1 kg
[E393]	Gas, natural, in ground[resource_in ground]	-14.3 Nm3
[E394]	Coal, hard, unspecified, in ground[resource_in ground]	-2.06 kg

Appendix C: Results of inventory analysis

[E395]	Coal, brown, in ground[resource_in ground]	-2.18 kg	[E395]	Coal, brown, in ground[resource_in ground]	-2.54 kg	[E395]	Coal, brown, in ground[resource_in ground]	-1.97 kg
[E396]	Peat, in ground[resource_biotic]	-0.00076 kg	[E396]	Peat, in ground[resource_biotic]	-0.00032 kg	[E396]	Peat, in ground[resource_biotic]	-0.0003 kg
[E397]	Wood, unspecified, standing[resource_biotic]	-4.20E-09 m3	[E397]	Wood, unspecified, standing[resource_biotic]	-2.87E-09 m3	[E397]	Wood, unspecified, standing[resource_biotic]	-2.69E-09 m3
[E398]	Energy, potential (in hydropower reservoir), converted[resource_in water]	-199 MJ	[E398]	Energy, potential (in hydropower reservoir), converted[resource_in water]	-197 MJ	[E398]	Energy, potential (in hydropower reservoir), converted[resource_in water]	-205 MJ
[E399]	Uranium, in ground[resource_in ground]	-0.00018 kg	[E399]	Uranium, in ground[resource_in ground]	-0.00017 kg	[E399]	Uranium, in ground[resource_in ground]	-1.47E-04 kg
[E400]	Aluminium, 24% in bauxite, 11% in crude ore, in ground[resource_in ground]	-0.0234 kg	[E400]	Aluminium, 24% in bauxite, 11% in crude ore, in ground[resource_in ground]	-0.0223 kg	[E400]	Aluminium, 24% in bauxite, 11% in crude ore, in ground[resource_in ground]	-0.0213 kg
[E401]	Clay, bentonite, in ground[resource_in ground]	-0.0312 kg	[E401]	Clay, bentonite, in ground[resource_in ground]	-0.0284 kg	[E401]	Clay, bentonite, in ground[resource_in ground]	-0.0277 kg
[E402]	Anhydrite, in ground[resource_in ground]	-1.35E-06 kg	[E402]	Anhydrite, in ground[resource_in ground]	-5.52E-07 kg	[E402]	Anhydrite, in ground[resource_in ground]	-5.27E-07 kg
[E403]	Clay, unspecified, in ground[resource_in ground]	-0.501 kg	[E403]	Clay, unspecified, in ground[resource_in ground]	-0.444 kg	[E403]	Clay, unspecified, in ground[resource_in ground]	-0.364 kg
[E404]	Chromium, 25.5% in chromite, 11.6% in crude ore, in ground[resource_in ground]	-0.00791 kg	[E404]	Chromium, 25.5% in chromite, 11.6% in crude ore, in ground[resource_in ground]	-0.00518 kg	[E404]	Chromium, 25.5% in chromite, 11.6% in crude ore, in ground[resource_in ground]	-0.00457 kg
[E405]	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00052 kg	[E405]	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00051 kg	[E405]	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00044 kg
[E406]	Dolomite, in ground[resource_in ground]	-0.00306 kg	[E406]	Dolomite, in ground[resource_in ground]	-0.00261 kg	[E406]	Dolomite, in ground[resource_in ground]	-0.00253 kg
[E407]	Iron, 46% in ore, 25% in crude ore, in ground[resource_in ground]	-1.39 kg	[E407]	Iron, 46% in ore, 25% in crude ore, in ground[resource_in ground]	-1.22 kg	[E407]	Iron, 46% in ore, 25% in crude ore, in ground[resource_in ground]	-1.17 kg
[E408]	Feldspar, in ground[resource_in ground]	-5.43E-09 kg	[E408]	Feldspar, in ground[resource_in ground]	-2.83E-09 kg	[E408]	Feldspar, in ground[resource_in ground]	-3.45E-09 kg
[E409]	Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground[resource_in ground]	-0.00165 kg	[E409]	Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground[resource_in ground]	-0.00128 kg	[E409]	Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground[resource_in ground]	-0.00118 kg
[E410]	Granite, in ground[resource_in ground]	-3.63E-11 kg	[E410]	Granite, in ground[resource_in ground]	-3.04E-11 kg	[E410]	Granite, in ground[resource_in ground]	-2.75E-11 kg
[E411]	Gravel, in ground[resource_in ground]	-151 kg	[E411]	Gravel, in ground[resource_in ground]	-20.9 kg	[E411]	Gravel, in ground[resource_in ground]	-19.9 kg
[E412]	Cinnabar, in ground[resource_in ground]	-9.78E-08 kg	[E412]	Cinnabar, in ground[resource_in ground]	-3.62E-06 kg	[E412]	Cinnabar, in ground[resource_in ground]	-3.00E-07 kg
[E413]	Magnesite, 60% in crude ore, in ground[resource_in ground]	-0.0184 kg	[E413]	Magnesite, 60% in crude ore, in ground[resource_in ground]	-0.016 kg	[E413]	Magnesite, 60% in crude ore, in ground[resource_in ground]	-0.0153 kg
[E414]	Nickel, 1.98% in silicates, 1.04% in crude ore, in ground[resource_in ground]	-0.0262 kg	[E414]	Nickel, 1.98% in silicates, 1.04% in crude ore, in ground[resource_in ground]	-0.0188 kg	[E414]	Nickel, 1.98% in silicates, 1.04% in crude ore, in ground[resource_in ground]	-0.0171 kg
[E415]	Olivine, in ground[resource_in ground]	-6.19E-07 kg	[E415]	Olivine, in ground[resource_in ground]	-2.27E-07 kg	[E415]	Olivine, in ground[resource_in ground]	-2.18E-07 kg
[E416]	Lead, 5.0% in sulfide, Pb 3.0%, Zn, Ag, Cd, In, in ground[resource_in ground]	-0.00661 kg	[E416]	Lead, 5.0% in sulfide, Pb 3.0%, Zn, Ag, Cd, In, in ground[resource_in ground]	-0.00623 kg	[E416]	Lead, 5.0% in sulfide, Pb 3.0%, Zn, Ag, Cd, In, in ground[resource_in ground]	-0.00621 kg
[E417]	Phosphorus, 18% in apatite, 12% in crude ore, in ground[resource_in ground]	-0.00027 kg	[E417]	Phosphorus, 18% in apatite, 12% in crude ore, in ground[resource_in ground]	-0.00029 kg	[E417]	Phosphorus, 18% in apatite, 12% in crude ore, in ground[resource_in ground]	-0.00025 kg
[E418]	TiO2, 95% in rutile, 0.40% in crude ore, in ground[resource_in ground]	-3.42E-08 kg	[E418]	TiO2, 95% in rutile, 0.40% in crude ore, in ground[resource_in ground]	-2.84E-08 kg	[E418]	TiO2, 95% in rutile, 0.40% in crude ore, in ground[resource_in ground]	-2.79E-08 kg
[E419]	Sulfur, in ground[resource_in ground]	-4.10E-05 kg	[E419]	Sulfur, in ground[resource_in ground]	-2.09E-05 kg	[E419]	Sulfur, in ground[resource_in ground]	-1.91E-05 kg
[E420]	Sand, unspecified, in ground[resource_in ground]	-5.28E-05 kg	[E420]	Sand, unspecified, in ground[resource_in ground]	-3.54E-05 kg	[E420]	Sand, unspecified, in ground[resource_in ground]	-3.03E-05 kg
[E421]	Shale, in ground[resource_in ground]	-3.82E-06 kg	[E421]	Shale, in ground[resource_in ground]	-1.56E-06 kg	[E421]	Shale, in ground[resource_in ground]	-1.49E-06 kg
[E422]	Sodium chloride, in ground[resource_in ground]	-0.327 kg	[E422]	Sodium chloride, in ground[resource_in ground]	-1.64 kg	[E422]	Sodium chloride, in ground[resource_in ground]	-0.393 kg
[E423]	Sodium nitrate, in ground[resource_in ground]	-1.72E-10 kg	[E423]	Sodium nitrate, in ground[resource_in ground]	-6.60E-11 kg	[E423]	Sodium nitrate, in ground[resource_in ground]	-6.44E-11 kg
[E424]	Talc, in ground[resource_in ground]	-8.08E-06 kg	[E424]	Talc, in ground[resource_in ground]	-1.18E-05 kg	[E424]	Talc, in ground[resource_in ground]	-7.29E-06 kg
[E425]	Zinc, 9.0% in sulfide, Zn 5.3%, Pb, Ag, Cd, In, in ground[resource_in ground]	-0.00487 kg	[E425]	Zinc, 9.0% in sulfide, Zn 5.3%, Pb, Ag, Cd, In, in ground[resource_in ground]	-0.0045 kg	[E425]	Zinc, 9.0% in sulfide, Zn 5.3%, Pb, Ag, Cd, In, in ground[resource_in ground]	-0.00439 kg
[E426]	Water, salt, ocean[resource_in water]	-0.0276 m3	[E426]	Water, salt, ocean[resource_in water]	-0.0274 m3	[E426]	Water, salt, ocean[resource_in water]	-0.026 m3
[E427]	Carbon monoxide, biogenic[air_high population density]	5.79E-05 kg	[E427]	Carbon monoxide, biogenic[air_high population density]	3.48E-05 kg	[E427]	Carbon monoxide, biogenic[air_high population density]	2.83E-05 kg
[E428]	Fluorine[air_high population density]	8.58E-08 kg	[E428]	Fluorine[air_high population density]	9.48E-08 kg	[E428]	Fluorine[air_high population density]	7.50E-08 kg
[E429]	Aldehydes, unspecified[air_high population density]	2.67E-07 kg	[E429]	Aldehydes, unspecified[air_high population density]	2.46E-07 kg	[E429]	Aldehydes, unspecified[air_high population density]	2.25E-07 kg
[E430]	Ethene, chloro-[air_high population density]	3.17E-07 kg	[E430]	Ethene, chloro-[air_high population density]	2.04E-07 kg	[E430]	Ethene, chloro-[air_high population density]	1.78E-07 kg
[E431]	Hydrocarbons, chlorinated[air_high population density]	5.79E-08 kg	[E431]	Hydrocarbons, chlorinated[air_high population density]	6.07E-08 kg	[E431]	Hydrocarbons, chlorinated[air_high population density]	5.36E-08 kg
[E432]	Cyanide[air_high population density]	3.56E-06 kg	[E432]	Cyanide[air_high population density]	9.92E-05 kg	[E432]	Cyanide[air_high population density]	7.80E-07 kg
[E433]	Hydrocarbons, aliphatic, alkanes, cyclic[air_high population density]	1.39E-07 kg	[E433]	Hydrocarbons, aliphatic, alkanes, cyclic[air_high population density]	1.29E-07 kg	[E433]	Hydrocarbons, aliphatic, alkanes, cyclic[air_high population density]	1.22E-07 kg
[E434]	Silver[air_high population density]	1.21E-09 kg	[E434]	Silver[air_high population density]	1.21E-09 kg	[E434]	Silver[air_high population density]	1.01E-09 kg
[E435]	Antimony[air_high population density]	3.55E-08 kg	[E435]	Antimony[air_high population density]	5.60E-09 kg	[E435]	Antimony[air_high population density]	4.74E-09 kg
[E436]	Xylene[air_high population density]	0.00452 kg	[E436]	Xylene[air_high population density]	0.0045 kg	[E436]	Xylene[air_high population density]	0.0045 kg
[E437]	Benzene, ethyl-[air_high population density]	8.53E-05 kg	[E437]	Benzene, ethyl-[air_high population density]	8.00E-05 kg	[E437]	Benzene, ethyl-[air_high population density]	7.97E-05 kg
[E438]	Styrene[air_high population density]	1.11E-07 kg	[E438]	Styrene[air_high population density]	8.80E-08 kg	[E438]	Styrene[air_high population density]	9.79E-08 kg
[E439]	Iron, ion[water_river]	0.000494 kg	[E439]	Iron, ion[water_river]	0.000335 kg	[E439]	Iron, ion[water_river]	0.000291 kg
[E440]	Acidity, unspecified[water_river]	1.46E-06 kg	[E440]	Acidity, unspecified[water_river]	9.36E-07 kg	[E440]	Acidity, unspecified[water_river]	9.26E-07 kg
[E441]	Hydrocarbons, unspecified[water_river]	1.18E-05 kg	[E441]	Hydrocarbons, unspecified[water_river]	7.88E-06 kg	[E441]	Hydrocarbons, unspecified[water_river]	7.49E-06 kg
[E442]	Oils, unspecified[water_river]	0.145 kg	[E442]	Oils, unspecified[water_river]	0.139 kg	[E442]	Oils, unspecified[water_river]	0.138 kg
[E443]	Chlorine[water_river]	1.39E-06 kg	[E443]	Chlorine[water_river]	4.40E-07 kg	[E443]	Chlorine[water_river]	2.49E-06 kg
[E444]	Dissolved solids[water_river]	0.000513 kg	[E444]	Dissolved solids[water_river]	0.000408 kg	[E444]	Dissolved solids[water_river]	0.000376 kg
[E445]	Ethene, chloro-[water_river]	3.43E-09 kg	[E445]	Ethene, chloro-[water_river]	1.92E-09 kg	[E445]	Ethene, chloro-[water_river]	1.64E-09 kg
[E446]	AOX, Adsorbable Organic Halogen as Cl[water_river]	2.30E-06 kg	[E446]	AOX, Adsorbable Organic Halogen as Cl[water_river]	2.19E-06 kg	[E446]	AOX, Adsorbable Organic Halogen as Cl[water_river]	2.15E-06 kg
[E447]	Tin, ion[water_river]	4.88E-07 kg	[E447]	Tin, ion[water_river]	9.94E-08 kg	[E447]	Tin, ion[water_river]	3.14E-08 kg
[E448]	Strontium[water_river]	0.00478 kg	[E448]	Strontium[water_river]	0.00448 kg	[E448]	Strontium[water_river]	0.00445 kg
[E450]	Kaolinite, 24% in crude ore, in ground[resource_in ground]	-0.00047 kg	[E450]	Kaolinite, 24% in crude ore, in ground[resource_in ground]	-0.00043 kg	[E450]	Kaolinite, 24% in crude ore, in ground[resource_in ground]	-0.00043 kg
[E451]	Krypton, in air[resource_in air]	8.79E-16 kg	[E451]	Krypton, in air[resource_in air]	6.96E-16 kg	[E451]	Krypton, in air[resource_in air]	-7.75E-16 kg
[E452]	Chromium VI[water_river]	5.73E-05 kg	[E452]	Chromium VI[water_river]	6.95E-05 kg	[E452]	Chromium VI[water_river]	4.65E-05 kg
[E453]	Kieserite, 25% in crude ore, in ground[resource_in ground]	-8.38E-06 kg	[E453]	Kieserite, 25% in crude ore, in ground[resource_in ground]	-7.59E-06 kg	[E453]	Kieserite, 25% in crude ore, in ground[resource_in ground]	-7.54E-06 kg
[E454]	Ozone[air_high population density]	9.22E-08 kg	[E454]	Ozone[air_high population density]	2.90E-08 kg	[E454]	Ozone[air_high population density]	1.66E-07 kg
[E455]	Fluorine, 4.5% in apatite, 3% in crude ore, in ground[resource_in ground]	-6.52E-05 kg	[E455]	Fluorine, 4.5% in apatite, 3% in crude ore, in ground[resource_in ground]	-7.04E-05 kg	[E455]	Fluorine, 4.5% in apatite, 3% in crude ore, in ground[resource_in ground]	-6.13E-05 kg
[E456]	Transformation, from mineral extraction site[resource_land]	-0.00128 m2	[E456]	Transformation, from mineral extraction site[resource_land]	-0.00025 m2	[E456]	Transformation, from mineral extraction site[resource_land]	-0.00021 m2
[E457]	Uranium-234[air_low population density]	0.000527 kBq	[E457]	Uranium-234[air_low population density]	0.000495 kBq	[E457]	Uranium-234[air_low population density]	0.000427 kBq
[E458]	Thorium-230[air_low population density]	0.000173 kBq	[E458]	Thorium-230[air_low population density]	0.000163 kBq	[E458]	Thorium-230[air_low population density]	1.41E-04 kBq
[E459]	Thorium-232[air_low population density]	6.11E-05 kBq	[E459]	Thorium-232[air_low population density]	7.09E-05 kBq	[E459]	Thorium-232[air_low population density]	5.50E-05 kBq

Appendix C: Results of inventory analysis

[E460]	Radioactive species, alpha emitters[water_river]	5.01E-06 kBq
[E461]	Oils, unspecified[soil_industrial]	5.76E-06 kg
[E462]	Phosphorus, 18% in apatite, 4% in crude ore, in ground[resource_in ground]	-0.00057 kg
[E463]	Fluorine, 4.5% in apatite, 1% in crude ore, in ground[resource_in ground]	-0.00014 kg
[E464]	Transformation, to forest[resource_land]	-0.0389 m2
[E465]	Fluoride[water_unspecified]	2.56E-06 kg
[E466]	Phosphorus[air_high population density]	6.50E-07 kg
[E467]	Barium[water_river]	0.00238 kg
[E468]	Molybdenum[water_river]	3.45E-06 kg
[E469]	Selenium[water_river]	1.96E-06 kg
[E470]	Silver, ion[water_river]	2.71E-06 kg
[E471]	Xylene[water_river]	0.00025 kg
[E472]	Aluminium[water_ocean]	0.000225 kg
[E473]	Barium[water_ocean]	0.000729 kg
[E474]	Boron[water_ocean]	6.83E-06 kg
[E475]	Chloride[water_ocean]	0.419 kg
[E476]	Cyanide[water_ocean]	3.97E-06 kg
[E477]	Hydrocarbons, aromatic[water_ocean]	0.000462 kg
[E478]	Iron, ion[water_ocean]	4.48E-05 kg
[E479]	Magnesium[water_ocean]	0.0046 kg
[E480]	Mercury[water_ocean]	2.02E-08 kg
[E481]	Molybdenum[water_ocean]	1.71E-07 kg
[E482]	Nitrate[water_ocean]	0.000173 kg
[E483]	Phosphorus[water_ocean]	6.62E-06 kg
[E484]	Potassium, ion[water_ocean]	0.00352 kg
[E485]	Selenium[water_ocean]	2.56E-07 kg
[E486]	Sodium, ion[water_ocean]	0.256 kg
[E487]	Strontium[water_ocean]	0.00152 kg
[E488]	Suspended solids, unspecified[water_ocean]	0.0381 kg
[E489]	t-Butyl methyl ether[water_ocean]	5.41E-06 kg
[E490]	Vanadium, ion[water_ocean]	5.11E-07 kg
[E491]	Vanadium, ion[water_river]	0.00011 kg
[E492]	Xylene[water_ocean]	9.87E-05 kg
[E493]	Ammonium, ion[water_ocean]	0.000112 kg
[E494]	PAH, polycyclic aromatic hydrocarbons[water_river]	1.28E-05 kg
[E495]	AOX, Adsorbable Organic Halogen as Cl[water_ocean]	3.21E-07 kg
[E496]	Benzene[water_ocean]	6.90E-05 kg
[E497]	PAH, polycyclic aromatic hydrocarbons[water_ocean]	6.63E-06 kg
[E498]	Sulfide[water_ocean]	1.79E-06 kg
[E499]	Benzene, ethyl-[water_river]	6.31E-05 kg
[E500]	Benzene, ethyl-[water_ocean]	2.01E-05 kg
[E501]	BOD5, Biological Oxygen Demand[water_ocean]	0.104 kg
[E502]	DOC, Dissolved Organic Carbon[water_ocean]	0.0335 kg
[E503]	Toluene[water_ocean]	0.000127 kg
[E504]	COD, Chemical Oxygen Demand[water_ocean]	0.106 kg
[E505]	Nitrogen, organic bound[water_river]	0.0239 kg
[E506]	Hydrocarbons, unspecified[water_ocean]	0.000198 kg
[E507]	Nitrogen, organic bound[water_ocean]	0.000105 kg
[E508]	Oils, unspecified[water_ocean]	0.0332 kg
[E509]	Phenol[water_ocean]	0.000105 kg
[E510]	Occupation, traffic area, road network[resource_land]	-2.17 m2a
[E511]	Occupation, dump site[resource_land]	-1.14 m2a
[E512]	Transformation, to traffic area, road network[resource_land]	-0.00967 m2
[E513]	Transformation, to dump site, residual material landfill[resource_land]	-4.37E-05 m2
[E514]	Silicon[air_high population density]	2.20E-05 kg
[E515]	Borax, in ground[resource_in ground]	-4.54E-07 kg
[E516]	Sodium formate[air_high population density]	7.06E-10 kg
[E517]	Sodium formate[water_river]	1.70E-09 kg
[E519]	Heat, waste[water_river]	49.5 MJ
[E520]	Sulfur hexafluoride[air_unspecified]	1.04E-06 kg
[E521]	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a[air_high population density]	1.04E-09 kg
[E522]	Methane, chlorodifluoro-, HCFC-22[air_high population density]	1.71E-08 kg
[E523]	Methane, trichlorofluoro-, CFC-11[air_high population density]	4.78E-12 kg
[E524]	Methane, dichlorodifluoro-, CFC-12[air_high population density]	1.18E-09 kg
[E525]	1,4-Butanediol[air_high population density]	2.04E-10 kg
[E526]	Acenaphthene[air_low population density]	1.01E-12 kg
[E527]	Acenaphthene[air_unspecified]	2.17E-14 kg
[E528]	Acetaldehyde[air_low population density]	1.65E-07 kg
[E529]	Acetaldehyde[air_unspecified]	8.37E-05 kg
[E530]	Acetic acid[air_low population density]	1.09E-06 kg
[E531]	Acetic acid[air_unspecified]	2.30E-05 kg
[E532]	Acetone[air_low population density]	7.04E-07 kg
[E533]	Acetonitrile[air_low population density]	4.55E-08 kg
[E534]	Acrolein[air_high population density]	2.60E-08 kg
[E535]	Acrolein[air_low population density]	1.23E-09 kg
[E536]	Acrolein[air_unspecified]	1.26E-11 kg
[E537]	Acrylic acid[air_high population density]	9.17E-09 kg
[E538]	Actinides, radioactive, unspecified[air_low population density]	4.09E-06 kBq
[E539]	Aerosols, radioactive, unspecified[air_low population density]	5.54E-05 kBq
[E540]	Aldehydes, unspecified[air_low population density]	1.47E-07 kg
[E541]	Aldehydes, unspecified[air_unspecified]	9.25E-11 kg

[E460]	Radioactive species, alpha emitters[water_river]	5.40E-06 kBq
[E461]	Oils, unspecified[soil_industrial]	6.25E-06 kg
[E462]	Phosphorus, 18% in apatite, 4% in crude ore, in ground[resource_in ground]	-0.00062 kg
[E463]	Fluorine, 4.5% in apatite, 1% in crude ore, in ground[resource_in ground]	-0.00016 kg
[E464]	Transformation, to forest[resource_land]	-0.00037 m2
[E465]	Fluoride[water_unspecified]	2.79E-06 kg
[E466]	Phosphorus[air_high population density]	6.85E-07 kg
[E467]	Barium[water_river]	0.00216 kg
[E468]	Molybdenum[water_river]	3.32E-06 kg
[E469]	Selenium[water_river]	2.84E-05 kg
[E470]	Silver, ion[water_river]	2.54E-06 kg
[E471]	Xylene[water_river]	0.000234 kg
[E472]	Aluminium[water_ocean]	0.000215 kg
[E473]	Barium[water_ocean]	0.000699 kg
[E474]	Boron[water_ocean]	6.55E-06 kg
[E475]	Chloride[water_ocean]	0.402 kg
[E476]	Cyanide[water_ocean]	3.91E-06 kg
[E477]	Hydrocarbons, aromatic[water_ocean]	0.000443 kg
[E478]	Iron, ion[water_ocean]	4.29E-05 kg
[E479]	Magnesium[water_ocean]	0.00441 kg
[E480]	Mercury[water_ocean]	1.96E-08 kg
[E481]	Molybdenum[water_ocean]	1.64E-07 kg
[E482]	Nitrate[water_ocean]	0.000167 kg
[E483]	Phosphorus[water_ocean]	6.34E-06 kg
[E484]	Potassium, ion[water_ocean]	0.00338 kg
[E485]	Selenium[water_ocean]	2.46E-07 kg
[E486]	Sodium, ion[water_ocean]	0.245 kg
[E487]	Strontium[water_ocean]	0.00145 kg
[E488]	Suspended solids, unspecified[water_ocean]	0.0368 kg
[E489]	t-Butyl methyl ether[water_ocean]	5.19E-06 kg
[E490]	Vanadium, ion[water_ocean]	4.90E-07 kg
[E491]	Vanadium, ion[water_river]	4.86E-05 kg
[E492]	Xylene[water_ocean]	9.47E-05 kg
[E493]	Ammonium, ion[water_ocean]	0.000107 kg
[E494]	PAH, polycyclic aromatic hydrocarbons[water_river]	1.20E-05 kg
[E495]	AOX, Adsorbable Organic Halogen as Cl[water_ocean]	3.08E-07 kg
[E496]	Benzene[water_ocean]	6.62E-05 kg
[E497]	PAH, polycyclic aromatic hydrocarbons[water_ocean]	6.36E-06 kg
[E498]	Sulfide[water_ocean]	1.71E-06 kg
[E499]	Benzene, ethyl-[water_river]	5.93E-05 kg
[E500]	Benzene, ethyl-[water_ocean]	1.92E-05 kg
[E501]	BOD5, Biological Oxygen Demand[water_ocean]	0.0985 kg
[E502]	DOC, Dissolved Organic Carbon[water_ocean]	0.0317 kg
[E503]	Toluene[water_ocean]	0.000122 kg
[E504]	COD, Chemical Oxygen Demand[water_ocean]	0.0998 kg
[E505]	Nitrogen, organic bound[water_river]	0.000135 kg
[E506]	Hydrocarbons, unspecified[water_ocean]	0.000191 kg
[E507]	Nitrogen, organic bound[water_ocean]	0.0001 kg
[E508]	Oils, unspecified[water_ocean]	0.0313 kg
[E509]	Phenol[water_ocean]	0.0001 kg
[E510]	Occupation, traffic area, road network[resource_land]	-0.754 m2a
[E511]	Occupation, dump site[resource_land]	-0.0209 m2a
[E512]	Transformation, to traffic area, road network[resource_land]	-0.00202 m2
[E513]	Transformation, to dump site, residual material landfill[resource_land]	-7.34E-05 m2
[E514]	Silicon[air_high population density]	1.94E-05 kg
[E515]	Borax, in ground[resource_in ground]	-3.94E-07 kg
[E516]	Sodium formate[air_high population density]	3.11E-09 kg
[E517]	Sodium formate[water_river]	7.47E-09 kg
[E519]	Heat, waste[water_river]	237 MJ
[E520]	Sulfur hexafluoride[air_unspecified]	1.11E-06 kg
[E521]	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a[air_high population density]	1.10E-09 kg
[E522]	Methane, chlorodifluoro-, HCFC-22[air_high population density]	1.75E-08 kg
[E523]	Methane, trichlorofluoro-, CFC-11[air_high population density]	5.07E-12 kg
[E524]	Methane, dichlorodifluoro-, CFC-12[air_high population density]	1.27E-09 kg
[E525]	1,4-Butanediol[air_high population density]	2.16E-10 kg
[E526]	Acenaphthene[air_low population density]	9.19E-13 kg
[E527]	Acenaphthene[air_unspecified]	2.04E-14 kg
[E528]	Acetaldehyde[air_low population density]	1.54E-07 kg
[E529]	Acetaldehyde[air_unspecified]	3.22E-05 kg
[E530]	Acetic acid[air_low population density]	1.01E-06 kg
[E531]	Acetic acid[air_unspecified]	2.17E-05 kg
[E532]	Acetone[air_low population density]	7.79E-07 kg
[E533]	Acetonitrile[air_low population density]	4.24E-08 kg
[E534]	Acrolein[air_high population density]	7.62E-09 kg
[E535]	Acrolein[air_low population density]	1.28E-09 kg
[E536]	Acrolein[air_unspecified]	1.18E-11 kg
[E537]	Acrylic acid[air_high population density]	9.76E-09 kg
[E538]	Actinides, radioactive, unspecified[air_low population density]	3.73E-06 kBq
[E539]	Aerosols, radioactive, unspecified[air_low population density]	5.71E-05 kBq
[E540]	Aldehydes, unspecified[air_low population density]	1.37E-07 kg
[E541]	Aldehydes, unspecified[air_unspecified]	8.69E-11 kg

[E460]	Radioactive species, alpha emitters[water_river]	4.69E-06 kBq
[E461]	Oils, unspecified[soil_industrial]	5.42E-06 kg
[E462]	Phosphorus, 18% in apatite, 4% in crude ore, in ground[resource_in ground]	-0.00054 kg
[E463]	Fluorine, 4.5% in apatite, 1% in crude ore, in ground[resource_in ground]	-0.00013 kg
[E464]	Transformation, to forest[resource_land]	-0.00028 m2
[E465]	Fluoride[water_unspecified]	2.41E-06 kg
[E466]	Phosphorus[air_high population density]	5.47E-07 kg
[E467]	Barium[water_river]	0.00215 kg
[E468]	Molybdenum[water_river]	2.84E-06 kg
[E469]	Selenium[water_river]	7.97E-07 kg
[E470]	Silver, ion[water_river]	2.53E-06 kg
[E471]	Xylene[water_river]	0.000233 kg
[E472]	Aluminium[water_ocean]	0.000215 kg
[E473]	Barium[water_ocean]	0.000695 kg
[E474]	Boron[water_ocean]	6.52E-06 kg
[E475]	Chloride[water_ocean]	0.4 kg
[E476]	Cyanide[water_ocean]	3.77E-06 kg
[E477]	Hydrocarbons, aromatic[water_ocean]	0.000441 kg
[E478]	Iron, ion[water_ocean]	4.27E-05 kg
[E479]	Magnesium[water_ocean]	0.00439 kg
[E480]	Mercury[water_ocean]	1.95E-08 kg
[E481]	Molybdenum[water_ocean]	1.63E-07 kg
[E482]	Nitrate[water_ocean]	0.000161 kg
[E483]	Phosphorus[water_ocean]	6.31E-06 kg
[E484]	Potassium, ion[water_ocean]	0.00336 kg
[E485]	Selenium[water_ocean]	2.44E-07 kg
[E486]	Sodium, ion[water_ocean]	0.244 kg
[E487]	Strontium[water_ocean]	0.00145 kg
[E488]	Suspended solids, unspecified[water_ocean]	0.0368 kg
[E489]	t-Butyl methyl ether[water_ocean]	5.16E-06 kg
[E490]	Vanadium, ion[water_ocean]	4.87E-07 kg
[E491]	Vanadium, ion[water_river]	1.80E-06 kg
[E492]	Xylene[water_ocean]	9.42E-05 kg
[E493]	Ammonium, ion[water_ocean]	0.000107 kg
[E494]	PAH, polycyclic aromatic hydrocarbons[water_river]	1.19E-05 kg
[E495]	AOX, Adsorbable Organic Halogen as Cl[water_ocean]	3.06E-07 kg
[E496]	Benzene[water_ocean]	6.58E-05 kg
[E497]	PAH, polycyclic aromatic hydrocarbons[water_ocean]	6.33E-06 kg
[E498]	Sulfide[water_ocean]	1.70E-06 kg
[E499]	Benzene, ethyl-[water_river]	5.91E-05 kg
[E500]	Benzene, ethyl-[water_ocean]	1.91E-05 kg
[E501]	BOD5, Biological Oxygen Demand[water_ocean]	0.098 kg
[E502]	DOC, Dissolved Organic Carbon[water_ocean]	0.0316 kg
[E503]	Toluene[water_ocean]	0.000121 kg
[E504]	COD, Chemical Oxygen Demand[water_ocean]	0.0994 kg
[E505]	Nitrogen, organic bound[water_river]	0.000133 kg
[E506]	Hydrocarbons, unspecified[water_ocean]	0.000191 kg
[E507]	Nitrogen, organic bound[water_ocean]	9.96E-05 kg
[E508]	Oils, unspecified[water_ocean]	0.0312 kg
[E509]	Phenol[water_ocean]	9.98E-05 kg
[E510]	Occupation, traffic area, road network[resource_land]	-0.751 m2a
[E511]	Occupation, dump site[resource_land]	-0.0161 m2a
[E512]	Transformation, to traffic area, road network[resource_land]	-0.00198 m2
[E513]	Transformation, to dump site, residual material landfill[resource_land]	-3.60E-05 m2
[E514]	Silicon[air_high population density]	1.56E-05 kg
[E515]	Borax, in ground[resource_in ground]	-3.95E-07 kg
[E516]	Sodium formate[air_high population density]	6.26E-10 kg
[E517]	Sodium formate[water_river]	1.51E-09 kg
[E519]	Heat, waste[water_river]	44 MJ
[E520]	Sulfur hexafluoride[air_unspecified]	8.93E-07 kg
[E521]	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a[air_high population density]	9.71E-10 kg
[E522]	Methane, chlorodifluoro-, HCFC-22[air_high population density]	1.59E-08 kg
[E523]	Methane, trichlorofluoro-, CFC-11[air_high population density]	4.49E-12 kg
[E524]	Methane, dichlorodifluoro-, CFC-12[air_high population density]	1.11E-09 kg
[E525]	1,4-Butanediol[air_high population density]	1.92E-10 kg
[E526]	Acenaphthene[air_low population density]	8.17E-13 kg
[E527]	Acenaphthene[air_unspecified]	2.00E-14 kg
[E528]	Acetaldehyde[air_low population density]	1.53E-07 kg
[E529]	Acetaldehyde[air_unspecified]	3.02E-05 kg
[E530]	Acetic acid[air_low population density]	1.01E-06 kg
[E531]	Acetic acid[air_unspecified]	2.00E-05 kg
[E532]	Acetone[air_low population density]	6.38E-07 kg
[E533]	Acetonitrile[air_low population density]	4.21E-08 kg
[E534]	Acrolein[air_high population density]	7.45E-09 kg
[E535]	Acrolein[air_low population density]	1.05E-09 kg
[E536]	Acrolein[air_unspecified]	1.16E-11 kg
[E537]	Acrylic acid[air_high population density]	8.63E-09 kg
[E538]	Actinides, radioactive, unspecified[air_low population density]	3.32E-06 kBq
[E539]	Aerosols, radioactive, unspecified[air_low population density]	4.69E-05 kBq
[E540]	Aldehydes, unspecified[air_low population density]	1.19E-07 kg
[E541]	Aldehydes, unspecified[air_unspecified]	8.51E-11 kg

Appendix C: Results of inventory analysis

[E542]	Aluminium[air_high population density]	1.21E-05 kg	2.35E-05 kg	8.45E-06 kg
[E543]	Aluminium[air_low population density]	8.60E-06 kg	7.56E-06 kg	7.25E-06 kg
[E544]	Aluminium[air_low population density, long-term]	0.00015 kg	1.41E-04 kg	1.22E-04 kg
[E545]	Aluminium[air_unspecified]	0.000525 kg	0.000517 kg	0.000451 kg
[E546]	Ammonia[air_unspecified]	0.000512 kg	0.000421 kg	0.000416 kg
[E547]	Antimony[air_low population density]	3.56E-07 kg	3.51E-07 kg	3.02E-07 kg
[E548]	Antimony[air_low population density, long-term]	1.36E-08 kg	1.27E-08 kg	1.10E-08 kg
[E549]	Antimony[air_unspecified]	1.81E-09 kg	1.51E-09 kg	1.24E-09 kg
[E550]	Antimony-124[air_low population density]	3.75E-09 kBq	2.80E-09 kBq	2.74E-09 kBq
[E551]	Antimony-125[air_low population density]	3.91E-08 kBq	2.93E-08 kBq	2.86E-08 kBq
[E552]	Argon-41[air_low population density]	0.0215 kBq	0.0244 kBq	0.0191 kBq
[E553]	Arsenic[air_low population density]	2.63E-06 kg	2.52E-06 kg	2.19E-06 kg
[E554]	Arsenic[air_low population density, long-term]	7.98E-07 kg	7.48E-07 kg	6.45E-07 kg
[E555]	Arsenic[air_unspecified]	1.09E-08 kg	9.08E-09 kg	7.47E-09 kg
[E556]	Arsine[air_high population density]	1.07E-13 kg	1.14E-13 kg	1.01E-13 kg
[E557]	Barium[air_high population density]	1.55E-06 kg	7.71E-06 kg	1.16E-07 kg
[E558]	Barium[air_low population density]	1.39E-06 kg	1.01E-06 kg	7.99E-07 kg
[E559]	Barium[air_low population density, long-term]	8.72E-07 kg	8.17E-07 kg	7.05E-07 kg
[E560]	Barium[air_unspecified]	2.61E-15 kg	2.38E-15 kg	2.09E-15 kg
[E561]	Barium-140[air_low population density]	2.54E-06 kBq	1.90E-06 kBq	1.86E-06 kBq
[E562]	Benzal chloride[air_unspecified]	1.60E-15 kg	1.50E-15 kg	1.47E-15 kg
[E563]	Benzaldehyde[air_high population density]	1.36E-08 kg	3.98E-09 kg	3.89E-09 kg
[E564]	Benzene[air_lower stratosphere + upper troposphere]	3.46E-11 kg	3.65E-11 kg	3.25E-11 kg
[E565]	Benzene[air_unspecified]	1.40E-05 kg	1.04E-05 kg	9.38E-06 kg
[E566]	Benzene, ethyl-[air_low population density]	1.86E-10 kg	1.69E-10 kg	1.51E-10 kg
[E567]	Benzene, hexachloro-[air_high population density]	2.45E-10 kg	4.07E-08 kg	1.47E-10 kg
[E568]	Benzene, hexachloro-[air_unspecified]	1.23E-08 kg	1.08E-08 kg	1.04E-08 kg
[E569]	Benzene, pentachloro-[air_high population density]	6.15E-10 kg	1.02E-07 kg	3.68E-10 kg
[E570]	Benzo(a)pyrene[air_unspecified]	9.56E-08 kg	6.28E-08 kg	6.01E-08 kg
[E571]	Beryllium[air_high population density]	1.80E-09 kg	2.18E-08 kg	1.30E-09 kg
[E572]	Beryllium[air_low population density]	3.07E-09 kg	2.79E-09 kg	2.54E-09 kg
[E573]	Beryllium[air_low population density, long-term]	1.90E-08 kg	1.78E-08 kg	1.54E-08 kg
[E574]	Beryllium[air_unspecified]	2.72E-09 kg	2.27E-09 kg	1.87E-09 kg
[E575]	Boron[air_high population density]	6.28E-07 kg	5.40E-07 kg	4.26E-07 kg
[E576]	Boron[air_low population density]	5.61E-05 kg	6.53E-05 kg	5.06E-05 kg
[E577]	Boron[air_low population density, long-term]	2.53E-07 kg	2.37E-07 kg	2.04E-07 kg
[E578]	Boron[air_unspecified]	1.51E-14 kg	1.37E-14 kg	1.21E-14 kg
[E579]	Boron trifluoride[air_high population density]	1.46E-15 kg	1.56E-15 kg	1.38E-15 kg
[E580]	Bromine[air_high population density]	1.68E-07 kg	1.25E-05 kg	1.55E-07 kg
[E581]	Bromine[air_low population density]	2.92E-05 kg	7.15E-06 kg	5.54E-06 kg
[E582]	Bromine[air_unspecified]	1.24E-14 kg	1.13E-14 kg	9.93E-15 kg
[E583]	Butadiene[air_low population density]	5.39E-12 kg	5.69E-12 kg	5.07E-12 kg
[E584]	Butadiene[air_lower stratosphere + upper troposphere]	3.28E-11 kg	3.46E-11 kg	3.08E-11 kg
[E585]	Butadiene[air_unspecified]	7.65E-11 kg	8.06E-11 kg	7.19E-11 kg
[E586]	Butane[air_low population density]	0.000143 kg	0.000142 kg	0.000143 kg
[E587]	Butane[air_unspecified]	2.28E-08 kg	2.15E-08 kg	2.10E-08 kg
[E588]	Butyrolactone[air_high population density]	5.50E-11 kg	5.85E-11 kg	5.17E-11 kg
[E589]	Cadmium[air_low population density, long-term]	2.06E-08 kg	1.93E-08 kg	1.66E-08 kg
[E590]	Cadmium[air_lower stratosphere + upper troposphere]	1.73E-14 kg	1.83E-14 kg	1.63E-14 kg
[E591]	Cadmium[air_unspecified]	7.60E-08 kg	5.28E-08 kg	4.99E-08 kg
[E592]	Calcium[air_low population density]	1.07E-06 kg	9.57E-07 kg	9.07E-07 kg
[E593]	Calcium[air_low population density, long-term]	4.89E-05 kg	4.59E-05 kg	3.96E-05 kg
[E594]	Carbon dioxide, biogenic[air_low population density]	0.0388 kg	0.0399 kg	0.0331 kg
[E595]	Carbon dioxide, biogenic[air_unspecified]	0.0267 kg	0.0248 kg	0.0204 kg
[E596]	Carbon dioxide, fossil[air_lower stratosphere + upper troposphere]	5.46E-06 kg	5.76E-06 kg	5.14E-06 kg
[E597]	Carbon dioxide, fossil[air_unspecified]	9.65 kg	4.3 kg	4.01 kg
[E598]	Carbon disulfide[air_low population density]	5.57E-05 kg	5.47E-05 kg	4.81E-05 kg
[E599]	Carbon disulfide[air_unspecified]	2.96E-16 kg	2.78E-16 kg	2.72E-16 kg
[E600]	Carbon monoxide, biogenic[air_low population density]	4.49E-05 kg	3.77E-05 kg	4.93E-05 kg
[E601]	Carbon monoxide, fossil[air_lower stratosphere + upper troposphere]	6.41E-09 kg	6.77E-09 kg	6.03E-09 kg
[E602]	Carbon monoxide, fossil[air_unspecified]	0.0609 kg	0.0409 kg	0.039 kg
[E603]	Carbon-14[air_low population density]	0.341 kBq	0.316 kBq	0.274 kBq
[E604]	Cerium-141[air_low population density]	6.17E-07 kBq	4.61E-07 kBq	4.51E-07 kBq
[E605]	Cesium-134[air_low population density]	2.95E-08 kBq	2.21E-08 kBq	2.16E-08 kBq
[E606]	Cesium-137[air_low population density]	5.24E-07 kBq	3.92E-07 kBq	3.83E-07 kBq
[E607]	Chlorine[air_low population density]	4.30E-08 kg	4.04E-08 kg	3.48E-08 kg
[E608]	Chlorine[air_low population density, long-term]	1.87E-06 kg	1.75E-06 kg	1.51E-06 kg
[E609]	Chlorine[air_unspecified]	1.53E-09 kg	1.42E-09 kg	1.35E-09 kg
[E610]	Chloroform[air_low population density]	1.94E-10 kg	1.77E-10 kg	1.57E-10 kg
[E611]	Chloroform[air_unspecified]	1.35E-16 kg	1.27E-16 kg	1.24E-16 kg
[E612]	Chlorosilane, trimethyl-[air_high population density]	2.76E-09 kg	2.28E-09 kg	2.38E-09 kg
[E613]	Chromium[air_lower stratosphere + upper troposphere]	8.67E-14 kg	9.14E-14 kg	8.15E-14 kg
[E614]	Chromium[air_unspecified]	1.62E-06 kg	1.33E-06 kg	1.27E-06 kg
[E615]	Chromium VI[air_low population density]	6.61E-07 kg	4.31E-07 kg	3.78E-07 kg
[E616]	Chromium VI[air_low population density, long-term]	9.70E-08 kg	9.10E-08 kg	7.84E-08 kg
[E617]	Chromium VI[air_unspecified]	6.13E-10 kg	4.67E-10 kg	3.91E-10 kg

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[E618]	Chromium-51[air_low population density]	3.95E-08 kBq	2.96E-08 kBq	2.89E-08 kBq
[E619]	Cobalt[air_low population density]	5.55E-07 kg	4.19E-07 kg	3.67E-07 kg
[E620]	Cobalt[air_low population density, long-term]	1.21E-07 kg	1.13E-07 kg	9.77E-08 kg
[E621]	Cobalt[air_unspecified]	3.63E-09 kg	3.03E-09 kg	2.49E-09 kg
[E622]	Cobalt-58[air_low population density]	5.50E-08 kBq	4.12E-08 kBq	4.02E-08 kBq
[E623]	Cobalt-60[air_low population density]	4.86E-07 kBq	3.64E-07 kBq	3.55E-07 kBq
[E624]	Copper[air_low population density, long-term]	1.27E-06 kg	1.19E-06 kg	1.03E-06 kg
[E625]	Copper[air_lower stratosphere + upper troposphere]	2.95E-12 kg	3.11E-12 kg	2.77E-12 kg
[E626]	Copper[air_unspecified]	6.84E-06 kg	3.05E-06 kg	2.90E-06 kg
[E627]	Cumene[air_high population density]	8.14E-06 kg	7.35E-06 kg	6.76E-06 kg
[E628]	Cumene[air_low population density]	1.08E-11 kg	9.81E-12 kg	8.73E-12 kg
[E629]	Cumene[air_unspecified]	1.21E-17 kg	1.14E-17 kg	1.11E-17 kg
[E630]	Cyanide[air_low population density]	4.11E-07 kg	3.10E-07 kg	2.76E-07 kg
[E631]	Cyanide[air_unspecified]	5.70E-15 kg	5.35E-15 kg	5.24E-15 kg
[E632]	Dinitrogen monoxide[air_lower stratosphere + upper troposphere]	5.20E-11 kg	5.49E-11 kg	4.89E-11 kg
[E633]	Dinitrogen monoxide[air_unspecified]	0.000307 kg	0.000164 kg	1.45E-04 kg
[E634]	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin[air_low population density]	1.62E-12 kg	1.56E-12 kg	1.45E-12 kg
[E635]	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin[air_unspecified]	1.17E-11 kg	1.01E-11 kg	9.64E-12 kg
[E636]	Ethane[air_high population density]	0.00132 kg	0.00127 kg	0.00128 kg
[E637]	Ethane[air_low population density]	0.00189 kg	0.0019 kg	0.00193 kg
[E638]	Ethane[air_unspecified]	3.38E-08 kg	3.17E-08 kg	3.11E-08 kg
[E639]	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a[air_low population density]	8.30E-09 kg	7.64E-09 kg	6.66E-09 kg
[E640]	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a[air_unspecified]	1.04E-05 kg	4.65E-06 kg	4.39E-06 kg
[E641]	Ethane, 1,1,1-trichloro-, HCFC-140[air_low population density]	3.95E-11 kg	3.60E-11 kg	3.20E-11 kg
[E642]	Ethane, 1,1,1-trichloro-, HCFC-140[air_unspecified]	2.49E-16 kg	2.34E-16 kg	2.29E-16 kg
[E643]	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113[air_high population density]	4.35E-10 kg	4.63E-10 kg	4.09E-10 kg
[E644]	Ethane, 1,1-difluoro-, HFC-152a[air_high population density]	7.52E-09 kg	7.54E-09 kg	6.28E-09 kg
[E645]	Ethane, 1,2-dichloro-[air_low population density]	7.89E-11 kg	7.20E-11 kg	6.40E-11 kg
[E646]	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114[air_low population density]	1.57E-07 kg	1.42E-07 kg	1.25E-07 kg
[E647]	Ethane, hexafluoro-, HFC-116[air_high population density]	3.02E-08 kg	3.21E-08 kg	2.84E-08 kg
[E648]	Ethane, hexafluoro-, HFC-116[air_unspecified]	5.37E-07 kg	5.18E-07 kg	4.93E-07 kg
[E649]	Ethanol[air_low population density]	4.63E-08 kg	4.28E-08 kg	3.77E-08 kg
[E650]	Ethene[air_low population density]	2.44E-05 kg	2.14E-05 kg	2.08E-05 kg
[E651]	Ethene, chloro-[air_unspecified]	9.12E-17 kg	8.57E-17 kg	8.40E-17 kg
[E652]	Ethene, tetrachloro-[air_high population density]	7.69E-12 kg	7.79E-12 kg	6.56E-12 kg
[E653]	Ethene, tetrachloro-[air_low population density]	8.49E-11 kg	7.74E-11 kg	6.89E-11 kg
[E654]	Ethene, tetrachloro-[air_unspecified]	1.97E-13 kg	1.85E-13 kg	1.82E-13 kg
[E655]	Ethyl cellulose[air_high population density]	3.33E-08 kg	3.54E-08 kg	3.13E-08 kg
[E656]	Ethylene oxide[air_low population density]	5.21E-11 kg	5.50E-11 kg	4.90E-11 kg
[E657]	Ethylene oxide[air_lower stratosphere + upper troposphere]	3.17E-10 kg	3.34E-10 kg	2.98E-10 kg
[E658]	Ethylene oxide[air_unspecified]	7.39E-10 kg	7.80E-10 kg	6.95E-10 kg
[E659]	Ethyne[air_low population density]	8.65E-07 kg	7.66E-07 kg	7.39E-07 kg
[E660]	Ethyne[air_unspecified]	1.47E-08 kg	1.31E-08 kg	1.26E-08 kg
[E661]	Fluorine[air_low population density]	3.55E-07 kg	3.12E-07 kg	2.75E-07 kg
[E662]	Fluorine[air_low population density, long-term]	9.17E-06 kg	8.60E-06 kg	7.41E-06 kg
[E663]	Fluorine[air_unspecified]	2.23E-10 kg	1.81E-10 kg	1.91E-10 kg
[E664]	Fluosilicic acid[air_high population density]	6.28E-07 kg	6.05E-07 kg	5.77E-07 kg
[E665]	Formaldehyde[air_low population density]	3.29E-06 kg	3.49E-06 kg	2.94E-06 kg
[E666]	Formaldehyde[air_lower stratosphere + upper troposphere]	2.73E-10 kg	2.88E-10 kg	2.57E-10 kg
[E667]	Formaldehyde[air_unspecified]	0.000155 kg	6.05E-05 kg	5.66E-05 kg
[E668]	Formic acid[air_low population density]	3.04E-07 kg	2.84E-07 kg	2.81E-07 kg
[E669]	Furan[air_low population density]	8.64E-08 kg	8.05E-08 kg	7.99E-08 kg
[E670]	Furan[air_unspecified]	1.94E-17 kg	1.82E-17 kg	1.78E-17 kg
[E671]	Heat, waste[air_lower stratosphere + upper troposphere]	7.91E-05 MJ	8.34E-05 MJ	7.43E-05 MJ
[E672]	Helium[air_low population density]	0.000333 kg	0.000307 kg	0.000306 kg
[E673]	Helium[air_unspecified]	6.22E-14 kg	6.90E-14 kg	5.68E-14 kg
[E674]	Heptane[air_high population density]	0.000852 kg	0.000799 kg	0.000796 kg
[E675]	Hexane[air_high population density]	0.00207 kg	0.00196 kg	0.00196 kg
[E676]	Hexane[air_low population density]	3.12E-06 kg	2.93E-06 kg	2.53E-06 kg
[E677]	Hexane[air_unspecified]	1.96E-08 kg	1.84E-08 kg	1.80E-08 kg
[E678]	Hydrocarbons, aliphatic, alkanes, cyclic[air_low population density]	1.14E-09 kg	1.04E-09 kg	9.28E-10 kg
[E679]	Hydrocarbons, aliphatic, alkanes, unspecified[air_low population density]	0.000114 kg	0.000116 kg	0.000116 kg
[E680]	Hydrocarbons, aliphatic, alkanes, unspecified[air_unspecified]	0.000194 kg	0.000173 kg	1.67E-04 kg
[E681]	Hydrocarbons, aliphatic, unsaturated[air_low population density]	9.09E-06 kg	1.03E-05 kg	8.15E-06 kg
[E682]	Hydrocarbons, aliphatic, unsaturated[air_unspecified]	4.65E-15 kg	4.23E-15 kg	3.72E-15 kg
[E683]	Hydrocarbons, aromatic[air_low population density]	5.50E-05 kg	5.55E-05 kg	5.65E-05 kg
[E684]	Hydrocarbons, aromatic[air_unspecified]	4.77E-05 kg	4.18E-05 kg	4.00E-05 kg
[E685]	Hydrocarbons, chlorinated[air_low population density]	4.01E-10 kg	3.66E-10 kg	3.25E-10 kg
[E686]	Hydrocarbons, chlorinated[air_unspecified]	4.69E-07 kg	3.77E-07 kg	4.10E-07 kg
[E687]	Hydrogen[air_unspecified]	1.36E-06 kg	1.28E-06 kg	1.19E-06 kg

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[E688]	Hydrogen chloride[air_low population density]	0.00697 kg
[E689]	Hydrogen chloride[air_lower stratosphere + upper troposphere]	1.49E-12 kg
[E690]	Hydrogen chloride[air_unspecified]	0.000171 kg
[E691]	Hydrogen peroxide[air_high population density]	2.47E-08 kg
[E692]	Hydrogen sulfide[air_low population density]	0.000266 kg
[E693]	Hydrogen sulfide[air_unspecified]	1.87E-05 kg
[E694]	Hydrogen-3, Tritium[air_low population density]	1.48 kBq
[E695]	Iodine[air_high population density]	1.21E-08 kg
[E696]	Iodine[air_low population density]	3.30E-06 kg
[E697]	Iodine[air_unspecified]	6.29E-15 kg
[E698]	Iodine-129[air_low population density]	0.000274 kBq
[E699]	Iodine-131[air_low population density]	0.00804 kBq
[E700]	Iodine-133[air_low population density]	3.51E-06 kBq
[E701]	Iodine-135[air_low population density]	1.01E-06 kBq
[E702]	Iron[air_low population density]	3.83E-06 kg
[E703]	Iron[air_low population density, long-term]	0.000164 kg
[E704]	Iron[air_unspecified]	7.61E-06 kg
[E705]	Isocyanic acid[air_high population density]	1.53E-07 kg
[E706]	Isoprene[air_low population density]	4.01E-09 kg
[E707]	Isoprene[air_unspecified]	2.59E-16 kg
[E708]	Krypton-85[air_low population density]	0.069 kBq
[E709]	Krypton-85m[air_low population density]	0.0376 kBq
[E710]	Krypton-87[air_low population density]	0.00889 kBq
[E711]	Krypton-88[air_low population density]	0.0113 kBq
[E712]	Krypton-89[air_low population density]	0.00463 kBq
[E713]	Lanthanum-140[air_low population density]	2.17E-07 kBq
[E714]	Lead[air_low population density, long-term]	1.35E-06 kg
[E715]	Lead[air_lower stratosphere + upper troposphere]	3.47E-14 kg
[E716]	Lead[air_unspecified]	5.57E-06 kg
[E717]	Lead-210[air_high population density]	4.90E-05 kBq
[E718]	Lead-210[air_unspecified]	2.61E-12 kBq
[E719]	Magnesium[air_high population density]	4.86E-06 kg
[E720]	Magnesium[air_low population density]	3.10E-06 kg
[E721]	Magnesium[air_low population density, long-term]	1.50E-05 kg
[E722]	Magnesium[air_unspecified]	4.69E-11 kg
[E723]	Manganese[air_high population density]	3.96E-07 kg
[E724]	Manganese[air_low population density]	1.52E-06 kg
[E725]	Manganese[air_low population density, long-term]	3.38E-06 kg
[E726]	Manganese[air_unspecified]	1.11E-06 kg
[E727]	Manganese-54[air_low population density]	2.02E-08 kBq
[E728]	Mercury[air_low population density]	1.10E-06 kg
[E729]	Mercury[air_low population density, long-term]	1.04E-08 kg
[E730]	Mercury[air_lower stratosphere + upper troposphere]	1.21E-16 kg
[E731]	Mercury[air_unspecified]	1.50E-06 kg
[E732]	Methane, biogenic[air_low population density]	0.0948 kg
[E733]	Methane, biogenic[air_unspecified]	0.000286 kg
[E734]	Methane, bromo-, Halon 1001[air_unspecified]	3.65E-16 kg
[E735]	Methane, bromochlorodifluoro-, Halon 1211[air_low population density]	5.22E-07 kg
[E736]	Methane, bromotrifluoro-, Halon 1301[air_high population density]	1.51E-12 kg
[E737]	Methane, bromotrifluoro-, Halon 1301[air_low population density]	2.68E-06 kg
[E738]	Methane, chlorodifluoro-, HCFC-22[air_low population density]	1.82E-06 kg
[E739]	Methane, dichloro-, HCC-30[air_low population density]	5.73E-10 kg
[E740]	Methane, dichlorodifluoro-, CFC-12[air_low population density]	1.88E-09 kg
[E741]	Methane, dichlorodifluoro-, CFC-12[air_unspecified]	2.43E-16 kg
[E742]	Methane, dichlorofluoro-, HCFC-21[air_high population density]	2.95E-12 kg
[E743]	Methane, fossil[air_lower stratosphere + upper troposphere]	8.67E-11 kg
[E744]	Methane, fossil[air_unspecified]	0.000323 kg
[E745]	Methane, monochloro-, R-40[air_high population density]	7.04E-11 kg
[E746]	Methane, monochloro-, R-40[air_low population density]	1.05E-09 kg
[E747]	Methane, tetrachloro-, R-10[air_unspecified]	1.09E-13 kg
[E748]	Methane, tetrafluoro-, R-14[air_high population density]	3.87E-10 kg
[E749]	Methane, tetrafluoro-, R-14[air_unspecified]	4.84E-06 kg
[E750]	Methane, trifluoro-, HFC-23[air_high population density]	9.37E-10 kg
[E751]	Methanol[air_low population density]	6.90E-06 kg
[E752]	Methanol[air_unspecified]	1.16E-05 kg
[E753]	Methyl acrylate[air_high population density]	1.04E-08 kg
[E754]	Methyl borate[air_high population density]	1.63E-12 kg
[E755]	Methyl ethyl ketone[air_high population density]	1.65E-05 kg
[E756]	Methyl formate[air_high population density]	4.23E-11 kg

[E688]	Hydrogen chloride[air_low population density]	0.000448 kg
[E689]	Hydrogen chloride[air_lower stratosphere + upper troposphere]	1.57E-12 kg
[E690]	Hydrogen chloride[air_unspecified]	0.000139 kg
[E691]	Hydrogen peroxide[air_high population density]	2.63E-08 kg
[E692]	Hydrogen sulfide[air_low population density]	0.000266 kg
[E693]	Hydrogen sulfide[air_unspecified]	1.76E-05 kg
[E694]	Hydrogen-3, Tritium[air_low population density]	1.47 kBq
[E695]	Iodine[air_high population density]	1.14E-08 kg
[E696]	Iodine[air_low population density]	3.84E-06 kg
[E697]	Iodine[air_unspecified]	5.73E-15 kg
[E698]	Iodine-129[air_low population density]	0.000268 kBq
[E699]	Iodine-131[air_low population density]	0.00933 kBq
[E700]	Iodine-133[air_low population density]	2.70E-06 kBq
[E701]	Iodine-135[air_low population density]	9.23E-07 kBq
[E702]	Iron[air_low population density]	3.22E-06 kg
[E703]	Iron[air_low population density, long-term]	0.000153 kg
[E704]	Iron[air_unspecified]	6.55E-06 kg
[E705]	Isocyanic acid[air_high population density]	1.64E-07 kg
[E706]	Isoprene[air_low population density]	3.74E-09 kg
[E707]	Isoprene[air_unspecified]	2.43E-16 kg
[E708]	Krypton-85[air_low population density]	0.0777 kBq
[E709]	Krypton-85m[air_low population density]	0.0286 kBq
[E710]	Krypton-87[air_low population density]	0.00697 kBq
[E711]	Krypton-88[air_low population density]	0.00874 kBq
[E712]	Krypton-89[air_low population density]	0.00348 kBq
[E713]	Lanthanum-140[air_low population density]	1.63E-07 kBq
[E714]	Lead[air_low population density, long-term]	1.26E-06 kg
[E715]	Lead[air_lower stratosphere + upper troposphere]	3.66E-14 kg
[E716]	Lead[air_unspecified]	4.83E-06 kg
[E717]	Lead-210[air_high population density]	4.64E-05 kBq
[E718]	Lead-210[air_unspecified]	2.38E-12 kBq
[E719]	Magnesium[air_high population density]	7.75E-06 kg
[E720]	Magnesium[air_low population density]	2.73E-06 kg
[E721]	Magnesium[air_low population density, long-term]	1.41E-05 kg
[E722]	Magnesium[air_unspecified]	4.40E-11 kg
[E723]	Manganese[air_high population density]	4.38E-07 kg
[E724]	Manganese[air_low population density]	1.31E-06 kg
[E725]	Manganese[air_low population density, long-term]	3.17E-06 kg
[E726]	Manganese[air_unspecified]	9.63E-07 kg
[E727]	Manganese-54[air_low population density]	1.51E-08 kBq
[E728]	Mercury[air_low population density]	8.58E-07 kg
[E729]	Mercury[air_low population density, long-term]	9.71E-09 kg
[E730]	Mercury[air_lower stratosphere + upper troposphere]	1.28E-16 kg
[E731]	Mercury[air_unspecified]	1.31E-06 kg
[E732]	Methane, biogenic[air_low population density]	0.0948 kg
[E733]	Methane, biogenic[air_unspecified]	0.000295 kg
[E734]	Methane, bromo-, Halon 1001[air_unspecified]	3.43E-16 kg
[E735]	Methane, bromochlorodifluoro-, Halon 1211[air_low population density]	5.29E-07 kg
[E736]	Methane, bromotrifluoro-, Halon 1301[air_high population density]	1.42E-12 kg
[E737]	Methane, bromotrifluoro-, Halon 1301[air_low population density]	2.50E-06 kg
[E738]	Methane, chlorodifluoro-, HCFC-22[air_low population density]	1.85E-06 kg
[E739]	Methane, dichloro-, HCC-30[air_low population density]	5.23E-10 kg
[E740]	Methane, dichlorodifluoro-, CFC-12[air_low population density]	1.90E-09 kg
[E741]	Methane, dichlorodifluoro-, CFC-12[air_unspecified]	2.28E-16 kg
[E742]	Methane, dichlorofluoro-, HCFC-21[air_high population density]	3.12E-12 kg
[E743]	Methane, fossil[air_lower stratosphere + upper troposphere]	9.14E-11 kg
[E744]	Methane, fossil[air_unspecified]	1.32E-04 kg
[E745]	Methane, monochloro-, R-40[air_high population density]	3.79E-11 kg
[E746]	Methane, monochloro-, R-40[air_low population density]	9.54E-10 kg
[E747]	Methane, tetrachloro-, R-10[air_unspecified]	1.02E-13 kg
[E748]	Methane, tetrafluoro-, R-14[air_high population density]	3.88E-10 kg
[E749]	Methane, tetrafluoro-, R-14[air_unspecified]	4.66E-06 kg
[E750]	Methane, trifluoro-, HFC-23[air_high population density]	9.94E-10 kg
[E751]	Methanol[air_low population density]	6.48E-06 kg
[E752]	Methanol[air_unspecified]	1.09E-05 kg
[E753]	Methyl acrylate[air_high population density]	1.11E-08 kg
[E754]	Methyl borate[air_high population density]	1.34E-12 kg
[E755]	Methyl ethyl ketone[air_high population density]	1.75E-05 kg
[E756]	Methyl formate[air_high population density]	4.45E-11 kg

[E688]	Hydrogen chloride[air_low population density]	0.000353 kg
[E689]	Hydrogen chloride[air_lower stratosphere + upper troposphere]	1.40E-12 kg
[E690]	Hydrogen chloride[air_unspecified]	0.000148 kg
[E691]	Hydrogen peroxide[air_high population density]	2.32E-08 kg
[E692]	Hydrogen sulfide[air_low population density]	0.000271 kg
[E693]	Hydrogen sulfide[air_unspecified]	1.58E-05 kg
[E694]	Hydrogen-3, Tritium[air_low population density]	1.23 kBq
[E695]	Iodine[air_high population density]	8.88E-09 kg
[E696]	Iodine[air_low population density]	2.98E-06 kg
[E697]	Iodine[air_unspecified]	5.04E-15 kg
[E698]	Iodine-129[air_low population density]	0.000226 kBq
[E699]	Iodine-131[air_low population density]	0.00723 kBq
[E700]	Iodine-133[air_low population density]	2.60E-06 kBq
[E701]	Iodine-135[air_low population density]	8.12E-07 kBq
[E702]	Iron[air_low population density]	3.09E-06 kg
[E703]	Iron[air_low population density, long-term]	1.32E-04 kg
[E704]	Iron[air_unspecified]	6.20E-06 kg
[E705]	Isocyanic acid[air_high population density]	1.35E-07 kg
[E706]	Isoprene[air_low population density]	3.71E-09 kg
[E707]	Isoprene[air_unspecified]	2.38E-16 kg
[E708]	Krypton-85[air_low population density]	0.0611 kBq
[E709]	Krypton-85m[air_low population density]	0.0276 kBq
[E710]	Krypton-87[air_low population density]	0.00663 kBq
[E711]	Krypton-88[air_low population density]	0.00839 kBq
[E712]	Krypton-89[air_low population density]	0.00339 kBq
[E713]	Lanthanum-140[air_low population density]	1.59E-07 kBq
[E714]	Lead[air_low population density, long-term]	1.09E-06 kg
[E715]	Lead[air_lower stratosphere + upper troposphere]	3.26E-14 kg
[E716]	Lead[air_unspecified]	4.62E-06 kg
[E717]	Lead-210[air_high population density]	3.60E-05 kBq
[E718]	Lead-210[air_unspecified]	2.09E-12 kBq
[E719]	Magnesium[air_high population density]	3.54E-06 kg
[E720]	Magnesium[air_low population density]	2.62E-06 kg
[E721]	Magnesium[air_low population density, long-term]	1.21E-05 kg
[E722]	Magnesium[air_unspecified]	4.31E-11 kg
[E723]	Manganese[air_high population density]	3.45E-07 kg
[E724]	Manganese[air_low population density]	1.11E-06 kg
[E725]	Manganese[air_low population density, long-term]	2.74E-06 kg
[E726]	Manganese[air_unspecified]	9.16E-07 kg
[E727]	Manganese-54[air_low population density]	1.48E-08 kBq
[E728]	Mercury[air_low population density]	8.09E-07 kg
[E729]	Mercury[air_low population density, long-term]	8.38E-09 kg
[E730]	Mercury[air_lower stratosphere + upper troposphere]	1.14E-16 kg
[E731]	Mercury[air_unspecified]	1.25E-06 kg
[E732]	Methane, biogenic[air_low population density]	0.0995 kg
[E733]	Methane, biogenic[air_unspecified]	0.000242 kg
[E734]	Methane, bromo-, Halon 1001[air_unspecified]	3.36E-16 kg
[E735]	Methane, bromochlorodifluoro-, Halon 1211[air_low population density]	5.40E-07 kg
[E736]	Methane, bromotrifluoro-, Halon 1301[air_high population density]	1.41E-12 kg
[E737]	Methane, bromotrifluoro-, Halon 1301[air_low population density]	2.49E-06 kg
[E738]	Methane, chlorodifluoro-, HCFC-22[air_low population density]	1.88E-06 kg
[E739]	Methane, dichloro-, HCC-30[air_low population density]	4.65E-10 kg
[E740]	Methane, dichlorodifluoro-, CFC-12[air_low population density]	1.93E-09 kg
[E741]	Methane, dichlorodifluoro-, CFC-12[air_unspecified]	2.23E-16 kg
[E742]	Methane, dichlorofluoro-, HCFC-21[air_high population density]	2.76E-12 kg
[E743]	Methane, fossil[air_lower stratosphere + upper troposphere]	8.15E-11 kg
[E744]	Methane, fossil[air_unspecified]	1.25E-04 kg
[E745]	Methane, monochloro-, R-40[air_high population density]	3.77E-11 kg
[E746]	Methane, monochloro-, R-40[air_low population density]	8.49E-10 kg
[E747]	Methane, tetrachloro-, R-10[air_unspecified]	9.99E-14 kg
[E748]	Methane, tetrafluoro-, R-14[air_high population density]	3.23E-10 kg
[E749]	Methane, tetrafluoro-, R-14[air_unspecified]	4.44E-06 kg
[E750]	Methane, trifluoro-, HFC-23[air_high population density]	8.79E-10 kg
[E751]	Methanol[air_low population density]	6.06E-06 kg
[E752]	Methanol[air_unspecified]	1.01E-05 kg
[E753]	Methyl acrylate[air_high population density]	9.79E-09 kg
[E754]	Methyl borate[air_high population density]	1.27E-12 kg
[E755]	Methyl ethyl ketone[air_high population density]	1.55E-05 kg
[E756]	Methyl formate[air_high population density]	3.94E-11 kg

Appendix C: Results of inventory analysis

[E757]	Molybdenum[air_low population density]	5.08E-08 kg	[E757]	Molybdenum[air_low population density]	5.86E-08 kg	[E757]	Molybdenum[air_low population density]	4.57E-08 kg
[E758]	Molybdenum[air_low population density, long-term]	2.62E-07 kg	[E758]	Molybdenum[air_low population density, long-term]	2.46E-07 kg	[E758]	Molybdenum[air_low population density, long-term]	2.12E-07 kg
[E759]	Molybdenum[air_unspecified]	9.71E-12 kg	[E759]	Molybdenum[air_unspecified]	9.82E-12 kg	[E759]	Molybdenum[air_unspecified]	8.14E-12 kg
[E760]	NMVOC, non-methane volatile organic compounds, unspecified origin[air_lower stratosphere + upper troposphere]	1.16E-09 kg	[E760]	NMVOC, non-methane volatile organic compounds, unspecified origin[air_lower stratosphere + upper troposphere]	1.23E-09 kg	[E760]	NMVOC, non-methane volatile organic compounds, unspecified origin[air_lower stratosphere + upper troposphere]	1.09E-09 kg
[E761]	NMVOC, non-methane volatile organic compounds, unspecified origin[air_unspecified]	0.0158 kg	[E761]	NMVOC, non-methane volatile organic compounds, unspecified origin[air_unspecified]	0.00867 kg	[E761]	NMVOC, non-methane volatile organic compounds, unspecified origin[air_unspecified]	0.00846 kg
[E762]	Nickel[air_low population density, long-term]	2.76E-07 kg	[E762]	Nickel[air_low population density, long-term]	2.59E-07 kg	[E762]	Nickel[air_low population density, long-term]	2.23E-07 kg
[E763]	Nickel[air_lower stratosphere + upper troposphere]	1.21E-13 kg	[E763]	Nickel[air_lower stratosphere + upper troposphere]	1.28E-13 kg	[E763]	Nickel[air_lower stratosphere + upper troposphere]	1.14E-13 kg
[E764]	Nickel[air_unspecified]	9.84E-07 kg	[E764]	Nickel[air_unspecified]	7.55E-07 kg	[E764]	Nickel[air_unspecified]	7.19E-07 kg
[E765]	Niobium-95[air_low population density]	2.40E-09 kBq	[E765]	Niobium-95[air_low population density]	1.80E-09 kBq	[E765]	Niobium-95[air_low population density]	1.76E-09 kBq
[E766]	Nitrate[air_low population density]	4.44E-07 kg	[E766]	Nitrate[air_low population density]	4.16E-07 kg	[E766]	Nitrate[air_low population density]	3.59E-07 kg
[E767]	Nitrate[air_low population density, long-term]	1.29E-06 kg	[E767]	Nitrate[air_low population density, long-term]	1.21E-06 kg	[E767]	Nitrate[air_low population density, long-term]	1.04E-06 kg
[E768]	Nitrobenzene[air_high population density]	6.94E-11 kg	[E768]	Nitrobenzene[air_high population density]	6.27E-11 kg	[E768]	Nitrobenzene[air_high population density]	6.14E-11 kg
[E769]	Nitrogen oxides[air_lower stratosphere + upper troposphere]	2.43E-08 kg	[E769]	Nitrogen oxides[air_lower stratosphere + upper troposphere]	2.56E-08 kg	[E769]	Nitrogen oxides[air_lower stratosphere + upper troposphere]	2.28E-08 kg
[E770]	Nitrogen oxides[air_unspecified]	0.0974 kg	[E770]	Nitrogen oxides[air_unspecified]	0.0328 kg	[E770]	Nitrogen oxides[air_unspecified]	0.0309 kg
[E771]	Noble gases, radioactive, unspecified[air_low population density]	2.63E+03 kBq	[E771]	Noble gases, radioactive, unspecified[air_low population density]	2.58E+03 kBq	[E771]	Noble gases, radioactive, unspecified[air_low population density]	2.17E+03 kBq
[E772]	Ozone[air_low population density]	3.19E-09 kg	[E772]	Ozone[air_low population density]	3.35E-09 kg	[E772]	Ozone[air_low population density]	2.97E-09 kg
[E773]	Ozone[air_unspecified]	8.80E-05 kg	[E773]	Ozone[air_unspecified]	8.80E-05 kg	[E773]	Ozone[air_unspecified]	7.36E-05 kg
[E774]	PAH, polycyclic aromatic hydrocarbons[air_unspecified]	6.57E-06 kg	[E774]	PAH, polycyclic aromatic hydrocarbons[air_unspecified]	3.06E-06 kg	[E774]	PAH, polycyclic aromatic hydrocarbons[air_unspecified]	2.94E-06 kg
[E775]	Particulates, < 2.5 um[air_low population density, long-term]	1.20E-04 kg	[E775]	Particulates, < 2.5 um[air_low population density, long-term]	1.13E-04 kg	[E775]	Particulates, < 2.5 um[air_low population density, long-term]	9.71E-05 kg
[E776]	Particulates, < 2.5 um[air_lower stratosphere + upper troposphere]	6.59E-11 kg	[E776]	Particulates, < 2.5 um[air_lower stratosphere + upper troposphere]	6.95E-11 kg	[E776]	Particulates, < 2.5 um[air_lower stratosphere + upper troposphere]	6.20E-11 kg
[E777]	Particulates, > 10 um[air_low population density, long-term]	0.0003 kg	[E777]	Particulates, > 10 um[air_low population density, long-term]	0.000281 kg	[E777]	Particulates, > 10 um[air_low population density, long-term]	0.000243 kg
[E778]	Particulates, > 2.5 um, and < 10um[air_low population density, long-term]	0.00018 kg	[E778]	Particulates, > 2.5 um, and < 10um[air_low population density, long-term]	0.000169 kg	[E778]	Particulates, > 2.5 um, and < 10um[air_low population density, long-term]	1.46E-04 kg
[E779]	Pentane[air_low population density]	5.67E-06 kg	[E779]	Pentane[air_low population density]	6.58E-06 kg	[E779]	Pentane[air_low population density]	5.11E-06 kg
[E780]	Pentane[air_unspecified]	2.84E-08 kg	[E780]	Pentane[air_unspecified]	2.66E-08 kg	[E780]	Pentane[air_unspecified]	2.61E-08 kg
[E781]	Phenol[air_low population density]	7.87E-07 kg	[E781]	Phenol[air_low population density]	6.39E-07 kg	[E781]	Phenol[air_low population density]	6.76E-07 kg
[E782]	Phenol[air_unspecified]	9.44E-09 kg	[E782]	Phenol[air_unspecified]	1.04E-08 kg	[E782]	Phenol[air_unspecified]	8.53E-09 kg
[E783]	Phenol, pentachloro-[air_high population density]	8.11E-11 kg	[E783]	Phenol, pentachloro-[air_high population density]	1.12E-08 kg	[E783]	Phenol, pentachloro-[air_high population density]	5.24E-11 kg
[E784]	Phenol, pentachloro-[air_low population density]	4.30E-08 kg	[E784]	Phenol, pentachloro-[air_low population density]	5.01E-08 kg	[E784]	Phenol, pentachloro-[air_low population density]	3.87E-08 kg
[E785]	Phosphine[air_high population density]	7.93E-12 kg	[E785]	Phosphine[air_high population density]	8.44E-12 kg	[E785]	Phosphine[air_high population density]	7.46E-12 kg
[E786]	Phosphorus[air_low population density]	6.51E-08 kg	[E786]	Phosphorus[air_low population density]	5.82E-08 kg	[E786]	Phosphorus[air_low population density]	5.45E-08 kg
[E787]	Phosphorus[air_low population density, long-term]	2.53E-07 kg	[E787]	Phosphorus[air_low population density, long-term]	2.37E-07 kg	[E787]	Phosphorus[air_low population density, long-term]	2.04E-07 kg
[E788]	Phosphorus[air_unspecified]	1.62E-09 kg	[E788]	Phosphorus[air_unspecified]	1.50E-09 kg	[E788]	Phosphorus[air_unspecified]	1.44E-09 kg
[E789]	Platinum[air_high population density]	1.14E-12 kg	[E789]	Platinum[air_high population density]	8.56E-13 kg	[E789]	Platinum[air_high population density]	8.35E-13 kg
[E790]	Platinum[air_low population density]	3.16E-12 kg	[E790]	Platinum[air_low population density]	3.26E-12 kg	[E790]	Platinum[air_low population density]	2.68E-12 kg
[E791]	Plutonium-238[air_low population density]	3.73E-11 kBq	[E791]	Plutonium-238[air_low population density]	3.66E-11 kBq	[E791]	Plutonium-238[air_low population density]	3.08E-11 kBq
[E792]	Plutonium-alpha[air_low population density]	8.56E-11 kBq	[E792]	Plutonium-alpha[air_low population density]	8.39E-11 kBq	[E792]	Plutonium-alpha[air_low population density]	7.07E-11 kBq
[E793]	Polonium-210[air_high population density]	8.96E-05 kBq	[E793]	Polonium-210[air_high population density]	8.48E-05 kBq	[E793]	Polonium-210[air_high population density]	6.58E-05 kBq
[E794]	Polonium-210[air_unspecified]	4.78E-12 kBq	[E794]	Polonium-210[air_unspecified]	4.35E-12 kBq	[E794]	Polonium-210[air_unspecified]	3.82E-12 kBq
[E795]	Polychlorinated biphenyls[air_high population density]	3.34E-13 kg	[E795]	Polychlorinated biphenyls[air_high population density]	3.56E-13 kg	[E795]	Polychlorinated biphenyls[air_high population density]	3.14E-13 kg
[E796]	Polychlorinated biphenyls[air_unspecified]	2.16E-08 kg	[E796]	Polychlorinated biphenyls[air_unspecified]	1.89E-08 kg	[E796]	Polychlorinated biphenyls[air_unspecified]	1.81E-08 kg
[E797]	Potassium[air_high population density]	4.14E-05 kg	[E797]	Potassium[air_high population density]	4.55E-05 kg	[E797]	Potassium[air_high population density]	3.60E-05 kg
[E798]	Potassium[air_low population density]	1.04E-06 kg	[E798]	Potassium[air_low population density]	9.12E-07 kg	[E798]	Potassium[air_low population density]	8.76E-07 kg
[E799]	Potassium[air_low population density, long-term]	2.57E-05 kg	[E799]	Potassium[air_low population density, long-term]	2.41E-05 kg	[E799]	Potassium[air_low population density, long-term]	2.08E-05 kg
[E800]	Potassium-40[air_high population density]	1.42E-05 kBq	[E800]	Potassium-40[air_high population density]	1.35E-05 kBq	[E800]	Potassium-40[air_high population density]	1.04E-05 kBq
[E801]	Potassium-40[air_unspecified]	6.43E-13 kBq	[E801]	Potassium-40[air_unspecified]	5.85E-13 kBq	[E801]	Potassium-40[air_unspecified]	5.15E-13 kBq
[E802]	Propanal[air_unspecified]	8.66E-16 kg	[E802]	Propanal[air_unspecified]	8.13E-16 kg	[E802]	Propanal[air_unspecified]	7.97E-16 kg
[E803]	Propane[air_low population density]	0.000614 kg	[E803]	Propane[air_low population density]	0.000616 kg	[E803]	Propane[air_low population density]	0.000625 kg
[E804]	Propane[air_unspecified]	1.74E-08 kg	[E804]	Propane[air_unspecified]	1.63E-08 kg	[E804]	Propane[air_unspecified]	1.60E-08 kg
[E805]	Propene[air_low population density]	2.49E-06 kg	[E805]	Propene[air_low population density]	2.38E-06 kg	[E805]	Propene[air_low population density]	2.17E-06 kg
[E806]	Propene[air_unspecified]	2.05E-11 kg	[E806]	Propene[air_unspecified]	1.93E-11 kg	[E806]	Propene[air_unspecified]	1.89E-11 kg
[E807]	Propionic acid[air_unspecified]	3.95E-10 kg	[E807]	Propionic acid[air_unspecified]	3.71E-10 kg	[E807]	Propionic acid[air_unspecified]	3.63E-10 kg
[E808]	Protactinium-234[air_low population density]	4.47E-05 kBq	[E808]	Protactinium-234[air_low population density]	4.19E-05 kBq	[E808]	Protactinium-234[air_low population density]	3.61E-05 kBq
[E809]	Radioactive species, other beta emitters[air_high population density]	0.0509 kBq	[E809]	Radioactive species, other beta emitters[air_high population density]	0.0478 kBq	[E809]	Radioactive species, other beta emitters[air_high population density]	0.0476 kBq
[E810]	Radioactive species, other beta emitters[air_low population density]	1.06E-06 kBq	[E810]	Radioactive species, other beta emitters[air_low population density]	1.18E-06 kBq	[E810]	Radioactive species, other beta emitters[air_low population density]	9.33E-07 kBq
[E811]	Radium-226[air_high population density]	1.26E-05 kBq	[E811]	Radium-226[air_high population density]	1.20E-05 kBq	[E811]	Radium-226[air_high population density]	9.28E-06 kBq
[E812]	Radium-226[air_unspecified]	6.75E-13 kBq	[E812]	Radium-226[air_unspecified]	6.14E-13 kBq	[E812]	Radium-226[air_unspecified]	5.40E-13 kBq
[E813]	Radium-228[air_high population density]	6.83E-05 kBq	[E813]	Radium-228[air_high population density]	6.47E-05 kBq	[E813]	Radium-228[air_high population density]	5.01E-05 kBq
[E814]	Radium-228[air_low population density]	7.21E-05 kBq	[E814]	Radium-228[air_low population density]	8.38E-05 kBq	[E814]	Radium-228[air_low population density]	6.50E-05 kBq
[E815]	Radium-228[air_unspecified]	2.00E-13 kBq	[E815]	Radium-228[air_unspecified]	1.82E-13 kBq	[E815]	Radium-228[air_unspecified]	1.60E-13 kBq
[E816]	Radon-220[air_high population density]	1.06E-06 kBq	[E816]	Radon-220[air_high population density]	1.01E-06 kBq	[E816]	Radon-220[air_high population density]	7.82E-07 kBq
[E817]	Radon-220[air_low population density]	0.00876 kBq	[E817]	Radon-220[air_low population density]	0.0102 kBq	[E817]	Radon-220[air_low population density]	0.00789 kBq
[E818]	Radon-220[air_unspecified]	1.40E-11 kBq	[E818]	Radon-220[air_unspecified]	1.28E-11 kBq	[E818]	Radon-220[air_unspecified]	1.12E-11 kBq
[E819]	Radon-222[air_high population density]	1.06E-06 kBq	[E819]	Radon-222[air_high population density]	1.01E-06 kBq	[E819]	Radon-222[air_high population density]	7.81E-07 kBq
[E820]	Radon-222[air_low population density, long-term]	5.76E+03 kBq	[E820]	Radon-222[air_low population density, long-term]	5.40E+03 kBq	[E820]	Radon-222[air_low population density, long-term]	4.65E+03 kBq
[E821]	Radon-222[air_unspecified]	7.88E-12 kBq	[E821]	Radon-222[air_unspecified]	7.17E-12 kBq	[E821]	Radon-222[air_unspecified]	6.31E-12 kBq
[E822]	Ruthenium-103[air_low population density]	5.28E-10 kBq	[E822]	Ruthenium-103[air_low population density]	3.95E-10 kBq	[E822]	Ruthenium-103[air_low population density]	3.86E-10 kBq
[E823]	Scandium[air_high population density]	1.33E-09 kg	[E823]	Scandium[air_high population density]	1.25E-09 kg	[E823]	Scandium[air_high population density]	9.73E-10 kg
[E824]	Scandium[air_low population density]	2.98E-09 kg	[E824]	Scandium[air_low population density]	2.68E-09 kg	[E824]	Scandium[air_low population density]	2.48E-09 kg
[E825]	Scandium[air_low population density, long-term]	5.39E-07 kg	[E825]	Scandium[air_low population density, long-term]	5.05E-07 kg	[E825]	Scandium[air_low population density, long-term]	4.35E-07 kg
[E826]	Selenium[air_low population density, long-term]	7.52E-08 kg	[E826]	Selenium[air_low population density, long-term]	7.05E-08 kg	[E826]	Selenium[air_low population density, long-term]	6.08E-08 kg

Appendix C: Results of inventory analysis

[E827]	Selenium[air_lower stratosphere + upper troposphere]	1.73E-14 kg	1.83E-14 kg	1.63E-14 kg
[E828]	Selenium[air_unspecified]	2.60E-08 kg	9.55E-09 kg	8.87E-09 kg
[E829]	Silicon[air_low population density]	1.50E-05 kg	1.34E-05 kg	1.28E-05 kg
[E830]	Silicon[air_low population density, long-term]	3.35E-05 kg	3.14E-05 kg	2.71E-05 kg
[E831]	Silicon[air_unspecified]	2.46E-13 kg	2.73E-13 kg	2.24E-13 kg
[E832]	Silver[air_low population density]	3.31E-12 kg	4.59E-12 kg	3.04E-12 kg
[E833]	Silver[air_low population density, long-term]	2.25E-08 kg	2.11E-08 kg	1.82E-08 kg
[E834]	Silver-110[air_low population density]	5.23E-09 kBq	3.91E-09 kBq	3.82E-09 kBq
[E835]	Sodium[air_low population density]	1.47E-05 kg	5.07E-07 kg	4.81E-07 kg
[E836]	Sodium[air_low population density, long-term]	8.84E-06 kg	8.29E-06 kg	7.15E-06 kg
[E837]	Sodium[air_unspecified]	9.37E-10 kg	7.24E-10 kg	8.29E-10 kg
[E838]	Sodium hydroxide[air_high population density]	9.20E-08 kg	9.79E-08 kg	8.65E-08 kg
[E839]	Strontium[air_high population density]	2.02E-07 kg	5.46E-07 kg	1.47E-07 kg
[E840]	Strontium[air_low population density]	8.92E-07 kg	9.95E-07 kg	7.88E-07 kg
[E841]	Strontium[air_low population density, long-term]	5.47E-07 kg	5.13E-07 kg	4.42E-07 kg
[E842]	Strontium[air_unspecified]	2.38E-15 kg	2.17E-15 kg	1.91E-15 kg
[E843]	Styrene[air_low population density]	5.96E-10 kg	6.83E-10 kg	5.33E-10 kg
[E844]	Styrene[air_unspecified]	5.70E-17 kg	5.35E-17 kg	5.24E-17 kg
[E845]	Sulfate[air_low population density]	3.36E-06 kg	3.15E-06 kg	2.71E-06 kg
[E846]	Sulfate[air_low population density, long-term]	1.39E-04 kg	1.30E-04 kg	1.12E-04 kg
[E847]	Sulfate[air_unspecified]	2.76E-08 kg	2.56E-08 kg	2.56E-08 kg
[E848]	Sulfur dioxide[air_lower stratosphere + upper troposphere]	1.73E-09 kg	1.83E-09 kg	1.63E-09 kg
[E849]	Sulfur hexafluoride[air_low population density]	9.09E-10 kg	9.44E-10 kg	8.06E-10 kg
[E850]	Sulfuric acid[air_high population density]	1.93E-08 kg	2.05E-08 kg	1.81E-08 kg
[E851]	Sulfuric acid[air_low population density]	7.49E-12 kg	7.49E-12 kg	6.24E-12 kg
[E852]	Terpenes[air_low population density]	3.79E-08 kg	3.53E-08 kg	3.51E-08 kg
[E853]	Thallium[air_high population density]	1.86E-09 kg	1.78E-08 kg	1.28E-09 kg
[E854]	Thallium[air_low population density]	5.77E-10 kg	4.65E-10 kg	4.43E-10 kg
[E855]	Thallium[air_unspecified]	1.18E-08 kg	9.83E-09 kg	8.08E-09 kg
[E856]	Thorium[air_high population density]	2.00E-09 kg	1.89E-09 kg	1.46E-09 kg
[E857]	Thorium[air_low population density]	1.99E-09 kg	1.75E-09 kg	1.68E-09 kg
[E858]	Thorium-228[air_high population density]	5.79E-06 kBq	5.49E-06 kBq	4.25E-06 kBq
[E859]	Thorium-228[air_unspecified]	1.08E-13 kBq	9.79E-14 kBq	8.62E-14 kBq
[E860]	Thorium-232[air_high population density]	3.69E-06 kBq	3.49E-06 kBq	2.71E-06 kBq
[E861]	Thorium-232[air_unspecified]	1.69E-13 kBq	1.54E-13 kBq	1.35E-13 kBq
[E862]	Thorium-234[air_low population density]	4.47E-05 kBq	4.19E-05 kBq	3.61E-05 kBq
[E863]	Tin[air_high population density]	8.04E-09 kg	1.95E-06 kg	7.44E-09 kg
[E864]	Tin[air_low population density]	4.98E-07 kg	4.28E-07 kg	3.77E-07 kg
[E865]	Tin[air_low population density, long-term]	3.14E-08 kg	2.94E-08 kg	2.54E-08 kg
[E866]	Tin[air_unspecified]	7.99E-08 kg	7.17E-08 kg	6.86E-08 kg
[E867]	Titanium[air_high population density]	1.23E-06 kg	4.13E-05 kg	9.25E-07 kg
[E868]	Titanium[air_low population density]	4.23E-07 kg	2.69E-07 kg	2.59E-07 kg
[E869]	Titanium[air_low population density, long-term]	9.83E-06 kg	9.21E-06 kg	7.94E-06 kg
[E870]	Titanium[air_unspecified]	1.81E-08 kg	1.59E-08 kg	1.52E-08 kg
[E871]	Toluene[air_low population density]	1.04E-05 kg	1.08E-05 kg	9.54E-06 kg
[E872]	Toluene[air_unspecified]	3.43E-05 kg	1.51E-05 kg	1.40E-05 kg
[E873]	Tungsten[air_low population density]	1.33E-10 kg	1.25E-10 kg	1.08E-10 kg
[E874]	Tungsten[air_low population density, long-term]	6.09E-08 kg	5.70E-08 kg	4.92E-08 kg
[E875]	Uranium[air_high population density]	2.66E-09 kg	2.52E-09 kg	1.95E-09 kg
[E876]	Uranium[air_low population density]	1.01E-09 kg	8.89E-10 kg	8.54E-10 kg
[E877]	Uranium alpha[air_low population density]	0.00242 kBq	0.00227 kBq	0.00196 kBq
[E878]	Uranium-235[air_low population density]	2.52E-05 kBq	2.36E-05 kBq	2.03E-05 kBq
[E879]	Uranium-238[air_high population density]	1.05E-05 kBq	9.98E-06 kBq	7.74E-06 kBq
[E880]	Uranium-238[air_unspecified]	5.62E-13 kBq	5.12E-13 kBq	4.50E-13 kBq
[E881]	Vanadium[air_low population density]	3.38E-07 kg	3.02E-07 kg	2.39E-07 kg
[E882]	Vanadium[air_low population density, long-term]	9.33E-07 kg	8.75E-07 kg	7.55E-07 kg
[E883]	Vanadium[air_unspecified]	5.41E-08 kg	4.73E-08 kg	4.49E-08 kg
[E884]	Water[air_high population density]	1.15E-07 kg	1.16E-07 kg	9.78E-08 kg
[E885]	Water[air_low population density]	3.54E-07 kg	3.73E-07 kg	3.33E-07 kg
[E886]	Water[air_lower stratosphere + upper troposphere]	2.15E-06 kg	2.27E-06 kg	2.02E-06 kg
[E887]	Water[air_unspecified]	0.000812 kg	0.0008 kg	0.000697 kg
[E888]	Xenon-131m[air_low population density]	0.0459 kBq	0.0357 kBq	0.0341 kBq
[E889]	Xenon-133[air_low population density]	1.66 kBq	1.28 kBq	1.23 kBq
[E890]	Xenon-133m[air_low population density]	0.00214 kBq	0.00189 kBq	0.00168 kBq
[E891]	Xenon-135[air_low population density]	0.664 kBq	0.513 kBq	0.492 kBq
[E892]	Xenon-135m[air_low population density]	0.416 kBq	0.32 kBq	0.308 kBq
[E893]	Xenon-137[air_low population density]	0.0127 kBq	0.00954 kBq	0.00929 kBq
[E894]	Xenon-138[air_low population density]	0.0956 kBq	0.0724 kBq	0.0702 kBq
[E895]	Xylene[air_low population density]	4.09E-05 kg	4.64E-05 kg	3.71E-05 kg
[E896]	Xylene[air_unspecified]	1.81E-05 kg	8.93E-06 kg	8.25E-06 kg
[E897]	Zinc[air_low population density, long-term]	9.66E-07 kg	9.06E-07 kg	7.81E-07 kg
[E898]	Zinc[air_lower stratosphere + upper troposphere]	1.73E-12 kg	1.83E-12 kg	1.63E-12 kg
[E899]	Zinc[air_unspecified]	2.05E-05 kg	1.61E-05 kg	1.52E-05 kg
[E900]	Zinc-65[air_low population density]	1.01E-07 kBq	7.56E-08 kBq	7.38E-08 kBq
[E901]	Zirconium[air_low population density]	2.45E-08 kg	2.15E-08 kg	2.07E-08 kg
[E902]	Zirconium-95[air_low population density]	9.88E-08 kBq	7.39E-08 kBq	7.22E-08 kBq
[E903]	t-Butyl methyl ether[air_high population density]	8.32E-08 kg	7.55E-08 kg	7.47E-08 kg
[E904]	Basalt, in ground[resource_in ground]	-0.00526 kg	-0.00426 kg	-0.00451 kg

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[E905]	Cadmium, 0.30% in sulfide, Cd 0.18%, Pb, Zn, Ag, In, in ground[resource_in ground]	-5.44E-05 kg
[E906]	Chrysotile, in ground[resource_in ground]	-1.09E-06 kg
[E907]	Cobalt, in ground[resource_in ground]	-2.20E-06 kg
[E908]	Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00284 kg
[E909]	Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00075 kg
[E910]	Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00378 kg
[E911]	Diatomite, in ground[resource_in ground]	-3.17E-08 kg
[E912]	Energy, gross calorific value, in biomass, primary forest[resource_biotic]	-0.00467 MJ
[E913]	Energy, kinetic (in wind), converted[resource_in air]	-0.894 MJ
[E914]	Gallium, 0.014% in bauxite, in ground[resource_in ground]	-5.81E-11 kg
[E915]	Gas, mine, off-gas, process, coal mining[resource_in ground]	-0.0232 Nm3
[E916]	Gold, Au 1.1E-4%, Ag 4.2E-3%, in ore, in ground[resource_in ground]	-3.26E-08 kg
[E917]	Gold, Au 1.3E-4%, Ag 4.6E-5%, in ore, in ground[resource_in ground]	-5.98E-08 kg
[E918]	Gold, Au 1.4E-4%, in ore, in ground[resource_in ground]	-7.16E-08 kg
[E919]	Gold, Au 2.1E-4%, Ag 2.1E-4%, in ore, in ground[resource_in ground]	-1.09E-07 kg
[E920]	Gold, Au 4.3E-4%, in ore, in ground[resource_in ground]	-2.71E-08 kg
[E921]	Gold, Au 4.9E-5%, in ore, in ground[resource_in ground]	-6.49E-08 kg
[E922]	Gold, Au 6.7E-4%, in ore, in ground[resource_in ground]	-1.01E-07 kg
[E923]	Gold, Au 7.1E-4%, in ore, in ground[resource_in ground]	-1.13E-07 kg
[E924]	Gold, Au 9.7E-4%, Ag 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore, in ground[resource_in ground]	-6.79E-09 kg
[E925]	Gypsum, in ground[resource_in ground]	-3.92E-06 kg
[E926]	Indium, 0.005% in sulfide, In 0.003%, Pb, Zn, Ag, Cd, in ground[resource_in ground]	-9.10E-07 kg
[E927]	2-Methyl-2-butene[air_high population density]	6.75E-16 kg
[E928]	Lithium, 0.15% in brine, in ground[resource_in ground]	-2.13E-10 kg
[E929]	Magnesium, 0.13% in water[resource_in water]	-2.09E-07 kg
[E930]	Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore, in ground[resource_in ground]	-7.02E-05 kg
[E931]	Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore, in ground[resource_in ground]	-9.89E-06 kg
[E932]	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore, in ground[resource_in ground]	-1.90E-05 kg
[E933]	Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore, in ground[resource_in ground]	-3.62E-05 kg
[E934]	Molybdenum, 0.11% in sulfide, Mo 4.1E-2% and Cu 0.36% in crude ore, in ground[resource_in ground]	-3.82E-05 kg
[E935]	Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground[resource_in ground]	-1.65E-05 kg
[E936]	Occupation, dump site, benthos[resource_land]	-0.0169 m2a
[E937]	Occupation, forest, intensive[resource_land]	-0.0206 m2a
[E938]	Occupation, forest, intensive, normal[resource_land]	-0.232 m2a
[E939]	Occupation, industrial area, benthos[resource_land]	-0.00015 m2a
[E940]	Occupation, shrub land, sclerophyllous[resource_land]	-0.189 m2a
[E941]	Occupation, traffic area, rail embankment[resource_land]	-0.00822 m2a
[E942]	Occupation, traffic area, rail network[resource_land]	-0.00909 m2a
[E943]	Occupation, traffic area, road embankment[resource_land]	-0.144 m2a
[E944]	Occupation, water bodies, artificial[resource_land]	-1.72 m2a
[E945]	Occupation, water courses, artificial[resource_land]	-0.0772 m2a
[E946]	Pd, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground[resource_in ground]	-5.96E-08 kg
[E947]	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_in ground]	-1.43E-07 kg
[E948]	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_in ground]	-1.50E-09 kg
[E949]	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_in ground]	-5.39E-09 kg
[E950]	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_in ground]	-1.23E-09 kg

[E905]	Cadmium, 0.30% in sulfide, Cd 0.18%, Pb, Zn, Ag, In, in ground[resource_in ground]	-4.89E-05 kg
[E906]	Chrysotile, in ground[resource_in ground]	-3.93E-05 kg
[E907]	Cobalt, in ground[resource_in ground]	-2.15E-06 kg
[E908]	Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00282 kg
[E909]	Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00075 kg
[E910]	Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00375 kg
[E911]	Diatomite, in ground[resource_in ground]	-2.98E-08 kg
[E912]	Energy, gross calorific value, in biomass, primary forest[resource_biotic]	-0.00435 MJ
[E913]	Energy, kinetic (in wind), converted[resource_in air]	-1.04 MJ
[E914]	Gallium, 0.014% in bauxite, in ground[resource_in ground]	-5.81E-11 kg
[E915]	Gas, mine, off-gas, process, coal mining[resource_in ground]	-0.0237 Nm3
[E916]	Gold, Au 1.1E-4%, Ag 4.2E-3%, in ore, in ground[resource_in ground]	-3.47E-08 kg
[E917]	Gold, Au 1.3E-4%, Ag 4.6E-5%, in ore, in ground[resource_in ground]	-6.37E-08 kg
[E918]	Gold, Au 1.4E-4%, in ore, in ground[resource_in ground]	-7.62E-08 kg
[E919]	Gold, Au 2.1E-4%, Ag 2.1E-4%, in ore, in ground[resource_in ground]	-1.16E-07 kg
[E920]	Gold, Au 4.3E-4%, in ore, in ground[resource_in ground]	-2.89E-08 kg
[E921]	Gold, Au 4.9E-5%, in ore, in ground[resource_in ground]	-6.91E-08 kg
[E922]	Gold, Au 6.7E-4%, in ore, in ground[resource_in ground]	-1.07E-07 kg
[E923]	Gold, Au 7.1E-4%, in ore, in ground[resource_in ground]	-1.21E-07 kg
[E924]	Gold, Au 9.7E-4%, Ag 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore, in ground[resource_in ground]	-7.23E-09 kg
[E925]	Gypsum, in ground[resource_in ground]	-3.99E-06 kg
[E926]	Indium, 0.005% in sulfide, In 0.003%, Pb, Zn, Ag, Cd, in ground[resource_in ground]	-8.18E-07 kg
[E927]	2-Methyl-2-butene[air_high population density]	5.44E-16 kg
[E928]	Lithium, 0.15% in brine, in ground[resource_in ground]	-1.72E-10 kg
[E929]	Magnesium, 0.13% in water[resource_in water]	-2.17E-07 kg
[E930]	Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore, in ground[resource_in ground]	-6.98E-05 kg
[E931]	Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore, in ground[resource_in ground]	-9.82E-06 kg
[E932]	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore, in ground[resource_in ground]	-1.49E-05 kg
[E933]	Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore, in ground[resource_in ground]	-3.60E-05 kg
[E934]	Molybdenum, 0.11% in sulfide, Mo 4.1E-2% and Cu 0.36% in crude ore, in ground[resource_in ground]	-2.99E-05 kg
[E935]	Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground[resource_in ground]	-2.65E-05 kg
[E936]	Occupation, dump site, benthos[resource_land]	-0.0164 m2a
[E937]	Occupation, forest, intensive[resource_land]	-0.0271 m2a
[E938]	Occupation, forest, intensive, normal[resource_land]	-0.245 m2a
[E939]	Occupation, industrial area, benthos[resource_land]	-0.00015 m2a
[E940]	Occupation, shrub land, sclerophyllous[resource_land]	-0.00143 m2a
[E941]	Occupation, traffic area, rail embankment[resource_land]	-0.00938 m2a
[E942]	Occupation, traffic area, rail network[resource_land]	-0.0104 m2a
[E943]	Occupation, traffic area, road embankment[resource_land]	-0.141 m2a
[E944]	Occupation, water bodies, artificial[resource_land]	-1.71 m2a
[E945]	Occupation, water courses, artificial[resource_land]	-0.0749 m2a
[E946]	Pd, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground[resource_in ground]	-5.77E-08 kg
[E947]	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_in ground]	-1.39E-07 kg
[E948]	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_in ground]	-1.45E-09 kg
[E949]	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_in ground]	-5.18E-09 kg
[E950]	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_in ground]	-1.18E-09 kg

[E905]	Cadmium, 0.30% in sulfide, Cd 0.18%, Pb, Zn, Ag, In, in ground[resource_in ground]	-4.87E-05 kg
[E906]	Chrysotile, in ground[resource_in ground]	-3.30E-06 kg
[E907]	Cobalt, in ground[resource_in ground]	-2.18E-06 kg
[E908]	Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00242 kg
[E909]	Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00064 kg
[E910]	Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-0.00323 kg
[E911]	Diatomite, in ground[resource_in ground]	-2.97E-08 kg
[E912]	Energy, gross calorific value, in biomass, primary forest[resource_biotic]	-0.00432 MJ
[E913]	Energy, kinetic (in wind), converted[resource_in air]	-0.807 MJ
[E914]	Gallium, 0.014% in bauxite, in ground[resource_in ground]	-4.84E-11 kg
[E915]	Gas, mine, off-gas, process, coal mining[resource_in ground]	-0.0201 Nm3
[E916]	Gold, Au 1.1E-4%, Ag 4.2E-3%, in ore, in ground[resource_in ground]	-3.07E-08 kg
[E917]	Gold, Au 1.3E-4%, Ag 4.6E-5%, in ore, in ground[resource_in ground]	-5.63E-08 kg
[E918]	Gold, Au 1.4E-4%, in ore, in ground[resource_in ground]	-6.74E-08 kg
[E919]	Gold, Au 2.1E-4%, Ag 2.1E-4%, in ore, in ground[resource_in ground]	-1.03E-07 kg
[E920]	Gold, Au 4.3E-4%, in ore, in ground[resource_in ground]	-2.55E-08 kg
[E921]	Gold, Au 4.9E-5%, in ore, in ground[resource_in ground]	-6.11E-08 kg
[E922]	Gold, Au 6.7E-4%, in ore, in ground[resource_in ground]	-9.46E-08 kg
[E923]	Gold, Au 7.1E-4%, in ore, in ground[resource_in ground]	-1.07E-07 kg
[E924]	Gold, Au 9.7E-4%, Ag 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore, in ground[resource_in ground]	-6.39E-09 kg
[E925]	Gypsum, in ground[resource_in ground]	-3.75E-06 kg
[E926]	Indium, 0.005% in sulfide, In 0.003%, Pb, Zn, Ag, Cd, in ground[resource_in ground]	-8.13E-07 kg
[E927]	2-Methyl-2-butene[air_high population density]	5.13E-16 kg
[E928]	Lithium, 0.15% in brine, in ground[resource_in ground]	-1.62E-10 kg
[E929]	Magnesium, 0.13% in water[resource_in water]	-1.85E-07 kg
[E930]	Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore, in ground[resource_in ground]	-6.00E-05 kg
[E931]	Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore, in ground[resource_in ground]	-8.44E-06 kg
[E932]	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore, in ground[resource_in ground]	-1.38E-05 kg
[E933]	Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore, in ground[resource_in ground]	-3.09E-05 kg
[E934]	Molybdenum, 0.11% in sulfide, Mo 4.1E-2% and Cu 0.36% in crude ore, in ground[resource_in ground]	-2.77E-05 kg
[E935]	Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground[resource_in ground]	-1.55E-05 kg
[E936]	Occupation, dump site, benthos[resource_land]	-0.0164 m2a
[E937]	Occupation, forest, intensive[resource_land]	-0.0168 m2a
[E938]	Occupation, forest, intensive, normal[resource_land]	-0.199 m2a
[E939]	Occupation, industrial area, benthos[resource_land]	-0.00015 m2a
[E940]	Occupation, shrub land, sclerophyllous[resource_land]	-0.00101 m2a
[E941]	Occupation, traffic area, rail embankment[resource_land]	-0.00769 m2a
[E942]	Occupation, traffic area, rail network[resource_land]	-0.00851 m2a
[E943]	Occupation, traffic area, road embankment[resource_land]	-0.14 m2a
[E944]	Occupation, water bodies, artificial[resource_land]	-1.79 m2a
[E945]	Occupation, water courses, artificial[resource_land]	-0.0734 m2a
[E946]	Pd, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground[resource_in ground]	-5.66E-08 kg
[E947]	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_in ground]	-1.36E-07 kg
[E948]	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_in ground]	-1.41E-09 kg
[E949]	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_in ground]	-5.07E-09 kg
[E950]	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_in ground]	-1.17E-09 kg

Appendix C: Results of inventory analysis

[E951]	Rh, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground[resource_in ground]	-3.86E-09 kg	[E951]	Rh, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground[resource_in ground]	-3.70E-09 kg	[E951]	Rh, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground[resource_in ground]	-3.67E-09 kg
[E952]	Rhenium, in crude ore, in ground[resource_in ground]	-2.17E-09 kg	[E952]	Rhenium, in crude ore, in ground[resource_in ground]	-2.06E-09 kg	[E952]	Rhenium, in crude ore, in ground[resource_in ground]	-2.05E-09 kg
[E953]	Silver, 0.007% in sulfide, Ag 0.004%, Pb, Zn, Cd, In, in ground[resource_in ground]	-7.26E-07 kg	[E953]	Silver, 0.007% in sulfide, Ag 0.004%, Pb, Zn, Cd, In, in ground[resource_in ground]	-7.72E-07 kg	[E953]	Silver, 0.007% in sulfide, Ag 0.004%, Pb, Zn, Cd, In, in ground[resource_in ground]	-6.82E-07 kg
[E954]	Silver, 3.2ppm in sulfide, Ag 1.2ppm, Cu and Te, in crude ore, in ground[resource_in ground]	-5.18E-07 kg	[E954]	Silver, 3.2ppm in sulfide, Ag 1.2ppm, Cu and Te, in crude ore, in ground[resource_in ground]	-5.51E-07 kg	[E954]	Silver, 3.2ppm in sulfide, Ag 1.2ppm, Cu and Te, in crude ore, in ground[resource_in ground]	-4.87E-07 kg
[E955]	Silver, Ag 2.1E-4%, Au 2.1E-4%, in ore, in ground[resource_in ground]	-4.78E-08 kg	[E955]	Silver, Ag 2.1E-4%, Au 2.1E-4%, in ore, in ground[resource_in ground]	-5.09E-08 kg	[E955]	Silver, Ag 2.1E-4%, Au 2.1E-4%, in ore, in ground[resource_in ground]	-4.49E-08 kg
[E956]	Silver, Ag 4.2E-3%, Au 1.1E-4%, in ore, in ground[resource_in ground]	-1.09E-07 kg	[E956]	Silver, Ag 4.2E-3%, Au 1.1E-4%, in ore, in ground[resource_in ground]	-1.16E-07 kg	[E956]	Silver, Ag 4.2E-3%, Au 1.1E-4%, in ore, in ground[resource_in ground]	-1.03E-07 kg
[E957]	Silver, Ag 4.6E-5%, Au 1.3E-4%, in ore, in ground[resource_in ground]	-1.07E-07 kg	[E957]	Silver, Ag 4.6E-5%, Au 1.3E-4%, in ore, in ground[resource_in ground]	-1.14E-07 kg	[E957]	Silver, Ag 4.6E-5%, Au 1.3E-4%, in ore, in ground[resource_in ground]	-1.01E-07 kg
[E958]	Silver, Ag 9.7E-4%, Au 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore, in ground[resource_in ground]	-7.06E-08 kg	[E958]	Silver, Ag 9.7E-4%, Au 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore, in ground[resource_in ground]	-7.51E-08 kg	[E958]	Silver, Ag 9.7E-4%, Au 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore, in ground[resource_in ground]	-6.64E-08 kg
[E959]	Sodium sulphate, various forms, in ground[resource_in ground]	-0.00115 kg	[E959]	Sodium sulphate, various forms, in ground[resource_in ground]	-0.00126 kg	[E959]	Sodium sulphate, various forms, in ground[resource_in ground]	-0.00109 kg
[E960]	Stibnite, in ground[resource_in ground]	-3.30E-09 kg	[E960]	Stibnite, in ground[resource_in ground]	-3.10E-09 kg	[E960]	Stibnite, in ground[resource_in ground]	-3.08E-09 kg
[E961]	Tantalum, 81.9% in tantalite, 1.6E-4% in crude ore, in ground[resource_in ground]	-5.72E-07 kg	[E961]	Tantalum, 81.9% in tantalite, 1.6E-4% in crude ore, in ground[resource_in ground]	-6.09E-07 kg	[E961]	Tantalum, 81.9% in tantalite, 1.6E-4% in crude ore, in ground[resource_in ground]	-5.38E-07 kg
[E962]	Tellurium, 0.5ppm in sulfide, Te 0.2ppm, Cu and Ag, in crude ore, in ground[resource_in ground]	-7.77E-08 kg	[E962]	Tellurium, 0.5ppm in sulfide, Te 0.2ppm, Cu and Ag, in crude ore, in ground[resource_in ground]	-8.26E-08 kg	[E962]	Tellurium, 0.5ppm in sulfide, Te 0.2ppm, Cu and Ag, in crude ore, in ground[resource_in ground]	-7.30E-08 kg
[E963]	TiO2, 54% in ilmenite, 2.6% in crude ore, in ground[resource_in ground]	-0.00613 kg	[E963]	TiO2, 54% in ilmenite, 2.6% in crude ore, in ground[resource_in ground]	-0.00704 kg	[E963]	TiO2, 54% in ilmenite, 2.6% in crude ore, in ground[resource_in ground]	-0.00581 kg
[E964]	Tin, 79% in cassiterite, 0.1% in crude ore, in ground[resource_in ground]	-3.09E-05 kg	[E964]	Tin, 79% in cassiterite, 0.1% in crude ore, in ground[resource_in ground]	-2.90E-05 kg	[E964]	Tin, 79% in cassiterite, 0.1% in crude ore, in ground[resource_in ground]	-2.58E-05 kg
[E965]	Transformation, from arable[resource_land]	-1.64E-05 m2	[E965]	Transformation, from arable[resource_land]	-1.58E-05 m2	[E965]	Transformation, from arable[resource_land]	-1.43E-05 m2
[E966]	Transformation, from arable, non-irrigated, fallow[resource_land]	-2.84E-06 m2	[E966]	Transformation, from arable, non-irrigated, fallow[resource_land]	-2.71E-06 m2	[E966]	Transformation, from arable, non-irrigated, fallow[resource_land]	-2.58E-06 m2
[E967]	Transformation, from dump site, inert material landfill[resource_land]	-0.00021 m2	[E967]	Transformation, from dump site, inert material landfill[resource_land]	-0.00016 m2	[E967]	Transformation, from dump site, inert material landfill[resource_land]	-0.00017 m2
[E968]	Transformation, from dump site, residual material landfill[resource_land]	-4.37E-05 m2	[E968]	Transformation, from dump site, residual material landfill[resource_land]	-7.34E-05 m2	[E968]	Transformation, from dump site, residual material landfill[resource_land]	-3.60E-05 m2
[E969]	Transformation, from dump site, sanitary landfill[resource_land]	-0.0375 m2	[E969]	Transformation, from dump site, sanitary landfill[resource_land]	-1.18E-05 m2	[E969]	Transformation, from dump site, sanitary landfill[resource_land]	-1.36E-06 m2
[E970]	Transformation, from dump site, slag compartment[resource_land]	-9.69E-07 m2	[E970]	Transformation, from dump site, slag compartment[resource_land]	-3.58E-05 m2	[E970]	Transformation, from dump site, slag compartment[resource_land]	-6.77E-07 m2
[E971]	Transformation, from industrial area[resource_land]	-8.72E-05 m2	[E971]	Transformation, from industrial area[resource_land]	-8.55E-05 m2	[E971]	Transformation, from industrial area[resource_land]	-8.38E-05 m2
[E972]	Transformation, from industrial area, benthos[resource_land]	-3.20E-07 m2	[E972]	Transformation, from industrial area, benthos[resource_land]	-3.24E-07 m2	[E972]	Transformation, from industrial area, benthos[resource_land]	-3.31E-07 m2
[E973]	Transformation, from sea and ocean[resource_land]	-0.017 m2	[E973]	Transformation, from sea and ocean[resource_land]	-0.0164 m2	[E973]	Transformation, from sea and ocean[resource_land]	-0.0164 m2
[E974]	Transformation, from shrub land, sclerophyllous[resource_land]	-0.0378 m2	[E974]	Transformation, from shrub land, sclerophyllous[resource_land]	-0.00035 m2	[E974]	Transformation, from shrub land, sclerophyllous[resource_land]	-0.00026 m2
[E975]	Transformation, from tropical rain forest[resource_land]	-4.18E-05 m2	[E975]	Transformation, from tropical rain forest[resource_land]	-3.90E-05 m2	[E975]	Transformation, from tropical rain forest[resource_land]	-3.87E-05 m2
[E976]	Transformation, to arable[resource_land]	-0.00063 m2	[E976]	Transformation, to arable[resource_land]	-0.00065 m2	[E976]	Transformation, to arable[resource_land]	-0.00064 m2
[E977]	Transformation, to arable, non-irrigated, fallow[resource_land]	-4.90E-06 m2	[E977]	Transformation, to arable, non-irrigated, fallow[resource_land]	-4.55E-06 m2	[E977]	Transformation, to arable, non-irrigated, fallow[resource_land]	-4.12E-06 m2
[E978]	Transformation, to dump site[resource_land]	-1.28E-04 m2	[E978]	Transformation, to dump site[resource_land]	-0.00013 m2	[E978]	Transformation, to dump site[resource_land]	-1.10E-04 m2
[E979]	Transformation, to dump site, benthos[resource_land]	-0.0169 m2	[E979]	Transformation, to dump site, benthos[resource_land]	-0.0164 m2	[E979]	Transformation, to dump site, benthos[resource_land]	-0.0164 m2
[E980]	Transformation, to dump site, inert material landfill[resource_land]	-0.00021 m2	[E980]	Transformation, to dump site, inert material landfill[resource_land]	-0.00016 m2	[E980]	Transformation, to dump site, inert material landfill[resource_land]	-0.00017 m2
[E981]	Transformation, to dump site, sanitary landfill[resource_land]	-0.0375 m2	[E981]	Transformation, to dump site, sanitary landfill[resource_land]	-1.18E-05 m2	[E981]	Transformation, to dump site, sanitary landfill[resource_land]	-1.36E-06 m2
[E982]	Transformation, to dump site, slag compartment[resource_land]	-9.69E-07 m2	[E982]	Transformation, to dump site, slag compartment[resource_land]	-3.58E-05 m2	[E982]	Transformation, to dump site, slag compartment[resource_land]	-6.77E-07 m2
[E983]	Transformation, to forest, intensive[resource_land]	-1.37E-04 m2	[E983]	Transformation, to forest, intensive[resource_land]	-0.00018 m2	[E983]	Transformation, to forest, intensive[resource_land]	-1.12E-04 m2
[E984]	Transformation, to forest, intensive, clear-cutting[resource_land]	-4.18E-05 m2	[E984]	Transformation, to forest, intensive, clear-cutting[resource_land]	-3.90E-05 m2	[E984]	Transformation, to forest, intensive, clear-cutting[resource_land]	-3.87E-05 m2
[E985]	Transformation, to forest, intensive, normal[resource_land]	-0.00173 m2	[E985]	Transformation, to forest, intensive, normal[resource_land]	-0.00183 m2	[E985]	Transformation, to forest, intensive, normal[resource_land]	-0.00148 m2
[E986]	Transformation, to heterogeneous, agricultural[resource_land]	-0.003 m2	[E986]	Transformation, to heterogeneous, agricultural[resource_land]	-0.00283 m2	[E986]	Transformation, to heterogeneous, agricultural[resource_land]	-0.00281 m2
[E987]	Transformation, to industrial area, benthos[resource_land]	-8.08E-06 m2	[E987]	Transformation, to industrial area, benthos[resource_land]	-7.69E-06 m2	[E987]	Transformation, to industrial area, benthos[resource_land]	-7.52E-06 m2
[E988]	Transformation, to sea and ocean[resource_land]	-3.20E-07 m2	[E988]	Transformation, to sea and ocean[resource_land]	-3.24E-07 m2	[E988]	Transformation, to sea and ocean[resource_land]	-3.31E-07 m2
[E989]	Transformation, to shrub land, sclerophyllous[resource_land]	-0.0378 m2	[E989]	Transformation, to shrub land, sclerophyllous[resource_land]	-0.00029 m2	[E989]	Transformation, to shrub land, sclerophyllous[resource_land]	-0.0002 m2
[E990]	Transformation, to traffic area, rail embankment[resource_land]	-1.91E-05 m2	[E990]	Transformation, to traffic area, rail embankment[resource_land]	-2.18E-05 m2	[E990]	Transformation, to traffic area, rail embankment[resource_land]	-1.79E-05 m2
[E991]	Transformation, to traffic area, rail network[resource_land]	-2.10E-05 m2	[E991]	Transformation, to traffic area, rail network[resource_land]	-2.40E-05 m2	[E991]	Transformation, to traffic area, rail network[resource_land]	-1.97E-05 m2
[E992]	Transformation, to traffic area, road embankment[resource_land]	-0.00037 m2	[E992]	Transformation, to traffic area, road embankment[resource_land]	-0.00036 m2	[E992]	Transformation, to traffic area, road embankment[resource_land]	-0.00036 m2
[E993]	Transformation, to water bodies, artificial[resource_land]	-0.0121 m2	[E993]	Transformation, to water bodies, artificial[resource_land]	-0.0113 m2	[E993]	Transformation, to water bodies, artificial[resource_land]	-0.0118 m2
[E994]	Transformation, to water courses, artificial[resource_land]	-0.0007 m2	[E994]	Transformation, to water courses, artificial[resource_land]	-0.00068 m2	[E994]	Transformation, to water courses, artificial[resource_land]	-0.00066 m2
[E995]	Ulexite, in ground[resource_in ground]	-1.92E-06 kg	[E995]	Ulexite, in ground[resource_in ground]	-2.21E-06 kg	[E995]	Ulexite, in ground[resource_in ground]	-1.74E-06 kg
[E996]	Vermiculite, in ground[resource_in ground]	-2.67E-06 kg	[E996]	Vermiculite, in ground[resource_in ground]	-8.21E-07 kg	[E996]	Vermiculite, in ground[resource_in ground]	-4.82E-06 kg
[E997]	Volume occupied, final repository for low-active radioactive waste[resource_in ground]	-3.73E-07 m3	[E997]	Volume occupied, final repository for low-active radioactive waste[resource_in ground]	-3.50E-07 m3	[E997]	Volume occupied, final repository for low-active radioactive waste[resource_in ground]	-3.02E-07 m3
[E998]	Volume occupied, final repository for radioactive waste[resource_in ground]	-8.61E-08 m3	[E998]	Volume occupied, final repository for radioactive waste[resource_in ground]	-8.25E-08 m3	[E998]	Volume occupied, final repository for radioactive waste[resource_in ground]	-7.03E-08 m3
[E999]	Volume occupied, reservoir[resource_in water]	-7.56 m3a	[E999]	Volume occupied, reservoir[resource_in water]	-7.51 m3a	[E999]	Volume occupied, reservoir[resource_in water]	-7.84 m3a
[E1000]	Volume occupied, underground deposit[resource_in ground]	-9.56E-07 m3	[E1000]	Volume occupied, underground deposit[resource_in ground]	-1.02E-06 m3	[E1000]	Volume occupied, underground deposit[resource_in ground]	-9.07E-07 m3
[E1001]	Water, lake[resource_in water]	-0.00279 m3	[E1001]	Water, lake[resource_in water]	-0.00085 m3	[E1001]	Water, lake[resource_in water]	-0.00507 m3

Appendix C: Results of inventory analysis

[E1002]	Water, turbine use, unspecified natural origin[resource_in water]	-506 m3	-496 m3	-502 m3
[E1003]	Wood, hard, standing[resource_biotic]	-7.51E-05 m3	-7.80E-05 m3	-6.47E-05 m3
[E1004]	Wood, primary forest, standing[resource_biotic]	-4.33E-07 m3	-4.04E-07 m3	-4.01E-07 m3
[E1005]	Wood, soft, standing[resource_biotic]	-0.00019 m3	-0.0002 m3	-0.00016 m3
[E1006]	Zirconium, 50% in zircon, 0.39% in crude ore, in ground[resource_in ground]	-7.82E-07 kg	-8.32E-07 kg	-7.35E-07 kg
[E1007]	Aldrin[soil_agricultural]	2.36E-10 kg	2.51E-10 kg	2.22E-10 kg
[E1008]	Aluminium[soil_agricultural]	7.40E-06 kg	1.30E-05 kg	7.02E-06 kg
[E1009]	Aluminium[soil_industrial]	0.00142 kg	0.00135 kg	0.00135 kg
[E1010]	Antimony[soil_agricultural]	1.59E-10 kg	2.20E-11 kg	1.84E-11 kg
[E1011]	Arsenic[soil_agricultural]	3.26E-09 kg	4.12E-09 kg	2.95E-09 kg
[E1012]	Arsenic[soil_industrial]	5.68E-07 kg	5.41E-07 kg	5.39E-07 kg
[E1013]	Barium[soil_agricultural]	4.96E-08 kg	4.55E-08 kg	4.53E-08 kg
[E1014]	Barium[soil_industrial]	0.00071 kg	0.000676 kg	0.000674 kg
[E1015]	Boron[soil_agricultural]	1.33E-08 kg	1.26E-08 kg	1.26E-08 kg
[E1016]	Boron[soil_industrial]	1.42E-05 kg	1.35E-05 kg	1.35E-05 kg
[E1017]	Boron[soil_unspecified]	1.21E-06 kg	1.04E-06 kg	9.36E-07 kg
[E1018]	Cadmium[soil_unspecified]	8.19E-09 kg	3.69E-09 kg	3.48E-09 kg
[E1019]	Calcium[soil_agricultural]	7.54E-05 kg	9.89E-05 kg	6.81E-05 kg
[E1020]	Calcium[soil_industrial]	0.00568 kg	0.00541 kg	0.00539 kg
[E1021]	Carbon[soil_agricultural]	3.99E-05 kg	1.01E-04 kg	4.18E-05 kg
[E1022]	Carbon[soil_industrial]	0.00426 kg	0.00406 kg	0.00404 kg
[E1023]	Chloride[soil_agricultural]	7.07E-07 kg	7.74E-07 kg	6.18E-07 kg
[E1024]	Chloride[soil_industrial]	0.00497 kg	0.00473 kg	0.00472 kg
[E1025]	Chloride[soil_unspecified]	0.161 kg	0.156 kg	0.156 kg
[E1026]	Chromium[soil_industrial]	7.10E-06 kg	6.76E-06 kg	6.74E-06 kg
[E1027]	Chromium[soil_unspecified]	3.90E-08 kg	1.76E-08 kg	1.66E-08 kg
[E1028]	Chromium VI[soil_unspecified]	6.86E-06 kg	5.87E-06 kg	5.29E-06 kg
[E1029]	Cobalt[soil_agricultural]	5.07E-09 kg	8.28E-09 kg	4.69E-09 kg
[E1030]	Copper[soil_industrial]	6.01E-08 kg	5.70E-08 kg	5.24E-08 kg
[E1031]	Copper[soil_unspecified]	4.83E-06 kg	3.91E-06 kg	3.53E-06 kg
[E1032]	Fluoride[soil_industrial]	7.10E-05 kg	6.76E-05 kg	6.74E-05 kg
[E1033]	Fluoride[soil_unspecified]	4.64E-06 kg	3.97E-06 kg	3.58E-06 kg
[E1034]	Glyphosate[soil_industrial]	5.53E-07 kg	6.31E-07 kg	5.18E-07 kg
[E1035]	Heat, waste[soil_industrial]	238 MJ	0.0145 MJ	0.0141 MJ
[E1036]	Heat, waste[soil_unspecified]	1.13 MJ	0.902 MJ	0.838 MJ
[E1037]	Iron[soil_agricultural]	2.91E-05 kg	7.66E-05 kg	3.03E-05 kg
[E1038]	Iron[soil_industrial]	0.00284 kg	0.00271 kg	0.0027 kg
[E1039]	Iron[soil_unspecified]	0.00105 kg	0.0012 kg	0.000986 kg
[E1040]	Lead[soil_unspecified]	3.37E-07 kg	1.52E-07 kg	1.43E-07 kg
[E1041]	Magnesium[soil_agricultural]	8.22E-06 kg	1.09E-05 kg	7.40E-06 kg
[E1042]	Magnesium[soil_industrial]	0.00114 kg	0.00108 kg	0.00108 kg
[E1043]	Manganese[soil_agricultural]	4.55E-06 kg	5.06E-06 kg	4.00E-06 kg
[E1044]	Manganese[soil_industrial]	5.68E-05 kg	5.41E-05 kg	5.39E-05 kg
[E1045]	Molybdenum[soil_agricultural]	1.46E-09 kg	3.22E-09 kg	1.43E-09 kg
[E1046]	Nickel[soil_unspecified]	1.06E-07 kg	4.76E-08 kg	4.50E-08 kg
[E1047]	Oils, biogenic[soil_forestry]	2.34E-06 kg	2.52E-06 kg	1.99E-06 kg
[E1048]	Oils, biogenic[soil_unspecified]	5.95E-06 kg	6.79E-06 kg	5.57E-06 kg
[E1049]	Oils, unspecified[soil_forestry]	0.178 kg	0.171 kg	0.17 kg
[E1050]	Oils, unspecified[soil_unspecified]	0.00093 kg	0.000872 kg	0.000867 kg
[E1051]	Phosphorus[soil_agricultural]	2.17E-06 kg	2.37E-06 kg	1.89E-06 kg
[E1052]	Phosphorus[soil_industrial]	7.10E-05 kg	6.76E-05 kg	6.74E-05 kg
[E1053]	Potassium[soil_agricultural]	1.20E-05 kg	1.32E-05 kg	1.05E-05 kg
[E1054]	Potassium[soil_industrial]	0.000497 kg	0.000473 kg	0.000472 kg
[E1055]	Silicon[soil_agricultural]	2.24E-05 kg	3.46E-05 kg	2.05E-05 kg
[E1056]	Silicon[soil_industrial]	0.000142 kg	0.000135 kg	0.000135 kg
[E1057]	Sodium[soil_industrial]	0.00284 kg	0.00271 kg	0.0027 kg
[E1058]	Sodium[soil_unspecified]	0.000317 kg	3.02E-04 kg	0.000307 kg
[E1059]	Strontium[soil_agricultural]	1.71E-07 kg	1.65E-07 kg	1.65E-07 kg
[E1060]	Strontium[soil_industrial]	1.42E-05 kg	1.35E-05 kg	1.35E-05 kg
[E1061]	Sulfur[soil_agricultural]	4.14E-06 kg	9.80E-06 kg	4.13E-06 kg
[E1062]	Sulfur[soil_industrial]	0.000852 kg	0.000812 kg	0.000809 kg
[E1063]	Sulfuric acid[soil_agricultural]	1.19E-11 kg	1.27E-11 kg	1.12E-11 kg
[E1064]	Tin[soil_agricultural]	3.03E-09 kg	9.80E-09 kg	3.07E-09 kg
[E1065]	Titanium[soil_agricultural]	3.05E-07 kg	3.34E-07 kg	2.67E-07 kg
[E1066]	Vanadium[soil_agricultural]	8.73E-09 kg	9.55E-09 kg	7.63E-09 kg
[E1067]	Zinc[soil_industrial]	2.13E-05 kg	2.03E-05 kg	2.02E-05 kg
[E1068]	Zinc[soil_unspecified]	2.31E-05 kg	1.04E-05 kg	9.82E-06 kg
[E1069]	1,4-Butanediol[water_river]	8.18E-11 kg	8.63E-11 kg	7.68E-11 kg
[E1070]	2-Methyl-2-butene[water_river]	1.62E-15 kg	1.30E-15 kg	1.23E-15 kg
[E1071]	4-Methyl-2-pentanone[water_unspecified]	9.47E-12 kg	8.90E-12 kg	8.72E-12 kg
[E1072]	AOX, Adsorbable Organic Halogen as Cl[water_unspecified]	1.08E-08 kg	1.01E-08 kg	9.41E-09 kg
[E1073]	Acenaphthene[water_ocean]	5.20E-09 kg	4.98E-09 kg	4.96E-09 kg
[E1074]	Acenaphthene[water_river]	1.64E-08 kg	1.54E-08 kg	1.53E-08 kg
[E1075]	Acenaphthylene[water_ocean]	3.25E-10 kg	3.12E-10 kg	3.10E-10 kg
[E1076]	Acenaphthylene[water_river]	1.02E-09 kg	9.61E-10 kg	9.57E-10 kg
[E1077]	Acetone[water_unspecified]	2.26E-11 kg	2.12E-11 kg	2.08E-11 kg
[E1078]	Acidity, unspecified[water_unspecified]	4.75E-10 kg	4.46E-10 kg	4.37E-10 kg
[E1079]	Acrylate, ion[water_river]	2.17E-08 kg	2.31E-08 kg	2.04E-08 kg
[E1080]	Actinides, radioactive, unspecified[water_ocean]	0.000445 kBq	0.000436 kBq	0.000367 kBq
[E1081]	Aluminium[water_ground-]	3.86E-05 kg	1.69E-05 kg	1.36E-05 kg
[E1082]	Aluminium[water_ground-, long-term]	0.16 kg	0.0259 kg	0.0132 kg
[E1083]	Aluminium[water_unspecified]	8.59E-07 kg	7.88E-07 kg	7.77E-07 kg
[E1084]	Ammonium, ion[water_ground-]	0.0113 kg	1.75E-06 kg	1.49E-06 kg
[E1085]	Ammonium, ion[water_ground-, long-term]	1.82 kg	9.07E-06 kg	8.84E-06 kg
[E1086]	Ammonium, ion[water_unspecified]	2.78E-08 kg	2.62E-08 kg	2.56E-08 kg
[E1087]	Antimony[water_ground-]	1.13E-05 kg	8.22E-07 kg	6.38E-07 kg
[E1088]	Antimony[water_ground-, long-term]	0.00304 kg	0.00143 kg	1.21E-05 kg
[E1089]	Antimony[water_river]	2.43E-05 kg	0.000771 kg	2.35E-06 kg
[E1090]	Antimony[water_unspecified]	2.54E-11 kg	2.39E-11 kg	2.34E-11 kg
[E1091]	Antimony-122[water_river]	1.51E-06 kBq	1.13E-06 kBq	1.10E-06 kBq
[E1092]	Antimony-124[water_river]	1.23E-04 kBq	1.08E-04 kBq	9.65E-05 kBq
[E1093]	Antimony-125[water_river]	1.17E-04 kBq	1.02E-04 kBq	9.13E-05 kBq
[E1094]	Arsenic, ion[water_ground-, long-term]	0.00137 kg	8.98E-05 kg	3.94E-05 kg
[E1095]	Arsenic, ion[water_lake]	4.25E-13 kg	4.52E-13 kg	4.00E-13 kg
[E1096]	Arsenic, ion[water_unspecified]	1.05E-07 kg	9.27E-08 kg	8.90E-08 kg
[E1097]	BOD5, Biological Oxygen Demand[water_ground-]	3.39E-07 kg	3.48E-07 kg	2.95E-07 kg
[E1098]	BOD5, Biological Oxygen Demand[water_ground-, long-term]	31.2 kg	0.248 kg	0.00494 kg
[E1099]	Barite[water_ocean]	0.0106 kg	0.0102 kg	0.0102 kg

Appendix C: Results of inventory analysis

[E1100]	Barium[water_ground-]	0.000499 kg
[E1101]	Barium[water_ground-, long-term]	0.131 kg
[E1102]	Barium[water_unspecified]	6.43E-07 kg
[E1103]	Barium-140[water_river]	6.62E-06 kBq
[E1104]	Benzene[water_unspecified]	3.79E-09 kg
[E1105]	Benzene, chloro-[water_river]	5.32E-07 kg
[E1106]	Benzene, ethyl-[water_unspecified]	2.13E-10 kg
[E1107]	Beryllium[water_ground-]	9.54E-08 kg
[E1108]	Beryllium[water_ground-, long-term]	0.000361 kg
[E1109]	Beryllium[water_river]	1.06E-07 kg
[E1110]	Beryllium[water_unspecified]	2.26E-11 kg
[E1111]	Boron[water_ground-]	4.61E-05 kg
[E1112]	Boron[water_ground-, long-term]	0.000592 kg
[E1113]	Boron[water_unspecified]	7.09E-09 kg
[E1114]	Bromine[water_ground-]	0.000413 kg
[E1115]	Bromine[water_ground-, long-term]	0.0478 kg
[E1116]	Bromine[water_ocean]	0.000585 kg
[E1117]	Bromine[water_river]	0.00309 kg
[E1118]	Bromine[water_unspecified]	4.84E-07 kg
[E1119]	Butyl acetate[water_river]	7.77E-08 kg
[E1120]	Butyrolactone[water_river]	1.32E-10 kg
[E1121]	COD, Chemical Oxygen Demand[water_ground-]	3.39E-07 kg
[E1122]	COD, Chemical Oxygen Demand[water_ground-, long-term]	132 kg
[E1123]	Cadmium, ion[water_ground-, long-term]	0.0568 kg
[E1124]	Cadmium, ion[water_lake]	3.61E-13 kg
[E1125]	Cadmium, ion[water_unspecified]	3.53E-07 kg
[E1126]	Calcium, ion[water_ground-, long-term]	0.216 kg
[E1127]	Calcium, ion[water_lake]	9.90E-07 kg
[E1128]	Calcium, ion[water_unspecified]	7.26E-06 kg
[E1129]	Carboxylic acids, unspecified[water_ocean]	0.00472 kg
[E1130]	Carboxylic acids, unspecified[water_river]	0.00968 kg
[E1131]	Cerium-141[water_river]	2.65E-06 kBq
[E1132]	Cerium-144[water_river]	8.06E-07 kBq
[E1133]	Cesium[water_ocean]	8.36E-07 kg
[E1134]	Cesium[water_river]	2.63E-06 kg
[E1135]	Cesium-134[water_river]	6.03E-05 kBq
[E1136]	Cesium-136[water_river]	4.70E-07 kBq
[E1137]	Cesium-137[water_ocean]	0.0509 kBq
[E1138]	Cesium-137[water_river]	0.000882 kBq
[E1139]	Chloride[water_ground-]	0.137 kg
[E1140]	Chloride[water_ground-, long-term]	13.3 kg
[E1141]	Chloride[water_river, long-term]	3.06E-08 kg
[E1142]	Chloride[water_unspecified]	0.00049 kg
[E1143]	Chlorinated solvents, unspecified[water_ocean]	6.90E-15 kg
[E1144]	Chromium VI[water_ground-]	2.07E-06 kg
[E1145]	Chromium VI[water_ground-, long-term]	0.000351 kg
[E1146]	Chromium VI[water_unspecified]	1.53E-07 kg
[E1147]	Chromium, ion[water_unspecified]	9.09E-07 kg
[E1148]	Chromium-51[water_river]	0.000507 kBq
[E1149]	Cobalt[water_ground-]	2.40E-05 kg
[E1150]	Cobalt[water_ground-, long-term]	0.0222 kg
[E1151]	Cobalt[water_ocean]	1.53E-09 kg
[E1152]	Cobalt[water_river]	3.72E-05 kg
[E1153]	Cobalt[water_unspecified]	5.01E-11 kg
[E1154]	Cobalt-57[water_river]	1.49E-05 kBq
[E1155]	Cobalt-58[water_river]	0.00232 kBq
[E1156]	Cobalt-60[water_river]	0.00203 kBq
[E1157]	Acenaphthene[air_high population density]	2.54E-10 kg
[E1158]	Copper, ion[water_ground-, long-term]	0.222 kg
[E1159]	Copper, ion[water_lake]	1.64E-11 kg
[E1160]	Copper, ion[water_unspecified]	1.54E-06 kg
[E1161]	Cumene[water_river]	1.96E-05 kg
[E1162]	Cyanide[water_unspecified]	1.05E-06 kg
[E1163]	DOC, Dissolved Organic Carbon[water_ground-, long-term]	121 kg
[E1164]	DOC, Dissolved Organic Carbon[water_lake]	2.31E-07 kg
[E1165]	Dissolved solids[water_ground-]	0.000364 kg
[E1166]	Dissolved solids[water_unspecified]	1.00E-04 kg
[E1167]	Fluoride[water_ground-, long-term]	0.0131 kg
[E1168]	Fluosilicic acid[water_river]	1.13E-06 kg
[E1169]	Formaldehyde[water_unspecified]	1.08E-06 kg
[E1170]	Glutaraldehyde[water_ocean]	1.30E-06 kg
[E1171]	Heat, waste[water_ground-, long-term]	3.37E+04 MJ
[E1172]	Heat, waste[water_ocean]	0.0023 MJ
[E1173]	Heat, waste[water_unspecified]	0.252 MJ
[E1174]	Hydrocarbons, aliphatic, alkanes, unspecified[water_ocean]	0.000109 kg
[E1175]	Hydrocarbons, aliphatic, alkanes, unspecified[water_river]	0.000342 kg
[E1176]	Hydrocarbons, aliphatic, unsaturated[water_ocean]	1.00E-05 kg
[E1177]	Hydrocarbons, aliphatic, unsaturated[water_river]	3.16E-05 kg
[E1178]	Hydrocarbons, unspecified[water_unspecified]	3.03E-06 kg
[E1179]	Hydrogen sulfide[water_ground-, long-term]	0.0766 kg
[E1180]	Hydrogen sulfide[water_river]	1.26E-06 kg
[E1181]	Hydrogen-3, Tritium[water_ocean]	106 kBq
[E1182]	Hydrogen-3, Tritium[water_river]	12 kBq
[E1183]	Hydroxide[water_river]	6.88E-07 kg
[E1184]	Hypochlorite[water_ocean]	1.99E-06 kg
[E1185]	Hypochlorite[water_river]	1.89E-06 kg
[E1186]	Iodide[water_ground-]	1.96E-07 kg
[E1187]	Iodide[water_ground-, long-term]	6.58E-12 kg
[E1188]	Iodide[water_ocean]	8.36E-05 kg
[E1189]	Iodine-131[water_river]	2.86E-05 kBq
[E1190]	Iodine-133[water_river]	4.16E-06 kBq
[E1191]	Iron, ion[water_ground-]	0.00364 kg

[E1100]	Barium[water_ground-]	2.49E-07 kg
[E1101]	Barium[water_ground-, long-term]	0.00703 kg
[E1102]	Barium[water_unspecified]	6.04E-07 kg
[E1103]	Barium-140[water_river]	4.95E-06 kBq
[E1104]	Benzene[water_unspecified]	3.56E-09 kg
[E1105]	Benzene, chloro-[water_river]	5.65E-07 kg
[E1106]	Benzene, ethyl-[water_unspecified]	2.00E-10 kg
[E1107]	Beryllium[water_ground-]	2.95E-08 kg
[E1108]	Beryllium[water_ground-, long-term]	2.84E-05 kg
[E1109]	Beryllium[water_river]	1.50E-08 kg
[E1110]	Beryllium[water_unspecified]	2.13E-11 kg
[E1111]	Boron[water_ground-]	4.65E-05 kg
[E1112]	Boron[water_ground-, long-term]	0.000611 kg
[E1113]	Boron[water_unspecified]	6.66E-09 kg
[E1114]	Bromine[water_ground-]	1.88E-06 kg
[E1115]	Bromine[water_ground-, long-term]	0.000718 kg
[E1116]	Bromine[water_ocean]	0.000561 kg
[E1117]	Bromine[water_river]	0.00512 kg
[E1118]	Bromine[water_unspecified]	4.55E-07 kg
[E1119]	Butyl acetate[water_river]	8.27E-08 kg
[E1120]	Butyrolactone[water_river]	1.40E-10 kg
[E1121]	COD, Chemical Oxygen Demand[water_ground-]	3.48E-07 kg
[E1122]	COD, Chemical Oxygen Demand[water_ground-, long-term]	0.757 kg
[E1123]	Cadmium, ion[water_ground-, long-term]	2.61E-05 kg
[E1124]	Cadmium, ion[water_lake]	3.84E-13 kg
[E1125]	Cadmium, ion[water_unspecified]	3.07E-07 kg
[E1126]	Calcium, ion[water_ground-, long-term]	0.265 kg
[E1127]	Calcium, ion[water_lake]	1.59E-06 kg
[E1128]	Calcium, ion[water_unspecified]	6.82E-06 kg
[E1129]	Carboxylic acids, unspecified[water_ocean]	0.00453 kg
[E1130]	Carboxylic acids, unspecified[water_river]	0.00909 kg
[E1131]	Cerium-141[water_river]	1.98E-06 kBq
[E1132]	Cerium-144[water_river]	6.03E-07 kBq
[E1133]	Cesium[water_ocean]	8.01E-07 kg
[E1134]	Cesium[water_river]	2.47E-06 kg
[E1135]	Cesium-134[water_river]	5.93E-05 kBq
[E1136]	Cesium-136[water_river]	3.51E-07 kBq
[E1137]	Cesium-137[water_ocean]	0.0499 kBq
[E1138]	Cesium-137[water_river]	0.00069 kBq
[E1139]	Chloride[water_ground-]	0.0232 kg
[E1140]	Chloride[water_ground-, long-term]	0.0564 kg
[E1141]	Chloride[water_river, long-term]	3.22E-08 kg
[E1142]	Chloride[water_unspecified]	0.000456 kg
[E1143]	Chlorinated solvents, unspecified[water_ocean]	7.15E-15 kg
[E1144]	Chromium VI[water_ground-]	2.41E-06 kg
[E1145]	Chromium VI[water_ground-, long-term]	0.000272 kg
[E1146]	Chromium VI[water_unspecified]	1.35E-07 kg
[E1147]	Chromium, ion[water_unspecified]	7.84E-07 kg
[E1148]	Chromium-51[water_river]	0.000387 kBq
[E1149]	Cobalt[water_ground-]	3.06E-07 kg
[E1150]	Cobalt[water_ground-, long-term]	0.000704 kg
[E1151]	Cobalt[water_ocean]	1.50E-09 kg
[E1152]	Cobalt[water_river]	1.08E-06 kg
[E1153]	Cobalt[water_unspecified]	4.70E-11 kg
[E1154]	Cobalt-57[water_river]	1.12E-05 kBq
[E1155]	Cobalt-58[water_river]	0.00183 kBq
[E1156]	Cobalt-60[water_river]	0.00159 kBq
[E1157]	Acenaphthene[air_high population density]	2.56E-10 kg
[E1158]	Copper, ion[water_ground-, long-term]	0.00149 kg
[E1159]	Copper, ion[water_lake]	1.74E-11 kg
[E1160]	Copper, ion[water_unspecified]	1.12E-06 kg
[E1161]	Cumene[water_river]	1.77E-05 kg
[E1162]	Cyanide[water_unspecified]	9.22E-07 kg
[E1163]	DOC, Dissolved Organic Carbon[water_ground-, long-term]	0.3 kg
[E1164]	DOC, Dissolved Organic Carbon[water_lake]	2.15E-07 kg
[E1165]	Dissolved solids[water_ground-]	0.000374 kg
[E1166]	Dissolved solids[water_unspecified]	9.43E-05 kg
[E1167]	Fluoride[water_ground-, long-term]	0.00341 kg
[E1168]	Fluosilicic acid[water_river]	1.09E-06 kg
[E1169]	Formaldehyde[water_unspecified]	1.01E-06 kg
[E1170]	Glutaraldehyde[water_ocean]	1.26E-06 kg
[E1171]	Heat, waste[water_ground-, long-term]	0.193 MJ
[E1172]	Heat, waste[water_ocean]	0.0021 MJ
[E1173]	Heat, waste[water_unspecified]	0.227 MJ
[E1174]	Hydrocarbons, aliphatic, alkanes, unspecified[water_ocean]	0.000104 kg
[E1175]	Hydrocarbons, aliphatic, alkanes, unspecified[water_river]	0.000321 kg
[E1176]	Hydrocarbons, aliphatic, unsaturated[water_ocean]	9.62E-06 kg
[E1177]	Hydrocarbons, aliphatic, unsaturated[water_river]	2.97E-05 kg
[E1178]	Hydrocarbons, unspecified[water_unspecified]	2.67E-06 kg
[E1179]	Hydrogen sulfide[water_ground-, long-term]	9.17E-05 kg
[E1180]	Hydrogen sulfide[water_river]	1.12E-06 kg
[E1181]	Hydrogen-3, Tritium[water_ocean]	104 kBq
[E1182]	Hydrogen-3, Tritium[water_river]	11.6 kBq
[E1183]	Hydroxide[water_river]	7.32E-07 kg
[E1184]	Hypochlorite[water_ocean]	2.27E-06 kg
[E1185]	Hypochlorite[water_river]	2.16E-06 kg
[E1186]	Iodide[water_ground-]	2.28E-07 kg
[E1187]	Iodide[water_ground-, long-term]	6.87E-12 kg
[E1188]	Iodide[water_ocean]	8.01E-05 kg
[E1189]	Iodine-131[water_river]	2.40E-05 kBq
[E1190]	Iodine-133[water_river]	3.11E-06 kBq
[E1191]	Iron, ion[water_ground-]	0.00409 kg

[E1100]	Barium[water_ground-]	2.01E-07 kg
[E1101]	Barium[water_ground-, long-term]	0.000249 kg
[E1102]	Barium[water_unspecified]	5.92E-07 kg
[E1103]	Barium-140[water_river]	4.84E-06 kBq
[E1104]	Benzene[water_unspecified]	3.49E-09 kg
[E1105]	Benzene, chloro-[water_river]	5.00E-07 kg
[E1106]	Benzene, ethyl-[water_unspecified]	1.96E-10 kg
[E1107]	Beryllium[water_ground-]	2.43E-08 kg
[E1108]	Beryllium[water_ground-, long-term]	9.86E-06 kg
[E1109]	Beryllium[water_river]	2.14E-09 kg
[E1110]	Beryllium[water_unspecified]	2.08E-11 kg
[E1111]	Boron[water_ground-]	4.04E-05 kg
[E1112]	Boron[water_ground-, long-term]	0.000521 kg
[E1113]	Boron[water_unspecified]	6.53E-09 kg
[E1114]	Bromine[water_ground-]	1.45E-06 kg
[E1115]	Bromine[water_ground-, long-term]	4.27E-06 kg
[E1116]	Bromine[water_ocean]	0.000558 kg
[E1117]	Bromine[water_river]	0.00174 kg
[E1118]	Bromine[water_unspecified]	4.46E-07 kg
[E1119]	Butyl acetate[water_river]	7.31E-08 kg
[E1120]	Butyrolactone[water_river]	1.24E-10 kg
[E1121]	COD, Chemical Oxygen Demand[water_ground-]	2.95E-07 kg
[E1122]	COD, Chemical Oxygen Demand[water_ground-, long-term]	0.0144 kg
[E1123]	Cadmium, ion[water_ground-, long-term]	1.42E-05 kg
[E1124]	Cadmium, ion[water_lake]	3.40E-13 kg
[E1125]	Cadmium, ion[water_unspecified]	2.95E-07 kg
[E1126]	Calcium, ion[water_ground-, long-term]	0.133 kg
[E1127]	Calcium, ion[water_lake]	9.28E-07 kg
[E1128]	Calcium, ion[water_unspecified]	6.68E-06 kg
[E1129]	Carboxylic acids, unspecified[water_ocean]	0.00451 kg
[E1130]	Carboxylic acids, unspecified[water_river]	0.00906 kg
[E1131]	Cerium-141[water_river]	1.93E-06 kBq
[E1132]	Cerium-144[water_river]	5.89E-07 kBq
[E1133]	Cesium[water_ocean]	7.97E-07 kg
[E1134]	Cesium[water_river]	2.46E-06 kg
[E1135]	Cesium-134[water_river]	4.99E-05 kBq
[E1136]	Cesium-136[water_river]	3.43E-07 kBq
[E1137]	Cesium-137[water_ocean]	0.0421 kBq
[E1138]	Cesium-137[water_river]	0.000657 kBq
[E1139]	Chloride[water_ground-]	0.0197 kg
[E1140]	Chloride[water_ground-, long-term]	0.0153 kg
[E1141]	Chloride[water_river, long-term]	2.87E-08 kg
[E1142]	Chloride[water_unspecified]	0.000453 kg
[E1143]	Chlorinated solvents, unspecified[water_ocean]	6.09E-15 kg
[E1144]	Chromium VI[water_ground-]	1.87E-06 kg
[E1145]	Chromium VI[water_ground-, long-term]	0.000187 kg
[E1146]	Chromium VI[water_unspecified]	1.29E-07 kg
[E1147]	Chromium, ion[water_unspecified]	7.53E-07 kg
[E1148]	Chromium-51[water_river]	0.000374 kBq
[E1149]	Cobalt[water_ground-]	2.48E-07 kg
[E1150]	Cobalt[water_ground-, long-term]	0.000163 kg
[E1151]	Cobalt[water_ocean]	1.27E-09 kg
[E1152]	Cobalt[water_river]	9.58E-07 kg
[E1153]	Cobalt[water_unspecified]	4.61E-11 kg
[E1154]	Cobalt-57[water_river]	1.09E-05 kBq
[E1155]	Cobalt-58[water_river]	0.00173 kBq
[E1156]	Cobalt-60[water_river]	0.00151 kBq
[E1157]	Acenaphthene[air_high population density]	2.64E-10 kg
[E1158]	Copper, ion[water_ground-, long-term]	0.000209 kg
[E1159]	Copper, ion[water_lake]	1.54E-11 kg
[E1160]	Copper, ion[water_unspecified]	1.07E-06 kg
[E1161]	Cumene[water_river]	1.63E-05 kg
[E1162]	Cyanide[water_unspecified]	8.86E-07 kg
[E1163]	DOC, Dissolved Organic Carbon[water_ground-, long-term]	0.00628 kg
[E1164]	DOC, Dissolved Organic Carbon[water_lake]	1.97E-07 kg
[E1165]	Dissolved solids[water_ground-]	0.000317 kg
[E1166]	Dissolved solids[water_unspecified]	9.24E-05 kg
[E1167]	Fluoride[water_ground-, long-term]	0.00256 kg
[E1168]	Fluosilicic acid[water_river]	1.04E-06 kg
[E1169]	Formaldehyde[water_unspecified]	9.41E-07 kg
[E1170]	Glutaraldehyde[water_ocean]	1.26E-06 kg
[E1171]	Heat, waste[water_ground-, long-term]	0.189 MJ
[E1172]	Heat, waste[water_ocean]	0.00184 MJ
[E1173]	Heat, waste[water_unspecified]	0.226 MJ
[E1174]	Hydrocarbons, aliphatic, alkanes, unspecified[water_ocean]	0.000104 kg
[E1175]	Hydrocarbons, aliphatic, alkanes, unspecified[water_river]	0.00032 kg
[E1176]	Hydrocarbons, aliphatic, unsaturated[water_ocean]	9.57E-06 kg
[E1177]	Hydrocarbons, aliphatic, unsaturated[water_river]	2.95E-05 kg
[E1178]	Hydrocarbons, unspecified[water_unspecified]	2.57E-06 kg
[E1179]	Hydrogen sulfide[water_ground-, long-term]	1.65E-05 kg
[E1180]	Hydrogen sulfide[water_river]	1.07E-06 kg
[E1181]	Hydrogen-3, Tritium[water_ocean]	87.4 kBq
[E1182]	Hydrogen-3, Tritium[water_river]	9.81 kBq
[E1183]	Hydroxide[water_river]	6.47E-07 kg
[E1184]	Hypochlorite[water_ocean]	1.77E-06 kg
[E1185]	Hypochlorite[water_river]	1.69E-06 kg
[E1186]	Iodide[water_ground-]	1.77E-07 kg
[E1187]	Iodide[water_ground-, long-term]	6.24E-12 kg
[E1188]	Iodide[water_ocean]	7.97E-05 kg
[E1189]	Iodine-131[water_river]	2.20E-05 kBq
[E1190]	Iodine-133[water_river]	3.04E-06 kBq
[E1191]	Iron, ion[water_ground-]	0.00317 kg

Appendix C: Results of inventory analysis

[E1192]	Iron, ion[water_ground-, long-term]	0.203 kg	0.0502 kg	0.0169 kg
[E1193]	Iron, ion[water_unspecified]	0.000192 kg	0.000179 kg	0.000177 kg
[E1194]	Iron-59[water_river]	1.14E-06 kBq	8.54E-07 kBq	8.35E-07 kBq
[E1195]	Lanthanum-140[water_river]	7.05E-06 kBq	5.27E-06 kBq	5.15E-06 kBq
[E1196]	Lead[water_ground-, long-term]	0.327 kg	9.37E-05 kg	3.51E-05 kg
[E1197]	Lead[water_lake]	1.07E-12 kg	1.14E-12 kg	1.01E-12 kg
[E1198]	Lead[water_unspecified]	1.03E-06 kg	7.61E-07 kg	7.28E-07 kg
[E1199]	Lead-210[water_river]	0.000382 kBq	0.000441 kBq	0.000344 kBq
[E1200]	Lead-210[water_unspecified]	6.54E-07 kBq	6.14E-07 kBq	6.02E-07 kBq
[E1201]	Lithium, ion[water_unspecified]	2.43E-06 kg	2.28E-06 kg	2.23E-06 kg
[E1202]	Magnesium[water_ground-]	0.000719 kg	0.0008 kg	0.00064 kg
[E1203]	Magnesium[water_ground-, long-term]	0.0725 kg	0.0827 kg	0.0644 kg
[E1204]	Magnesium[water_unspecified]	1.42E-06 kg	1.33E-06 kg	1.30E-06 kg
[E1205]	Manganese[water_ground-, long-term]	0.0605 kg	0.00794 kg	0.00538 kg
[E1206]	Manganese[water_unspecified]	9.84E-07 kg	8.66E-07 kg	8.33E-07 kg
[E1207]	Manganese-54[water_river]	1.40E-04 kBq	1.11E-04 kBq	1.05E-04 kBq
[E1208]	Mercury[water_ground-, long-term]	0.000596 kg	2.65E-06 kg	1.82E-06 kg
[E1209]	Mercury[water_lake]	9.26E-15 kg	9.85E-15 kg	8.70E-15 kg
[E1210]	Mercury[water_unspecified]	5.86E-08 kg	5.16E-08 kg	4.96E-08 kg
[E1211]	Methanol[water_ocean]	6.93E-06 kg	7.02E-06 kg	7.17E-06 kg
[E1212]	Methanol[water_unspecified]	3.23E-07 kg	3.02E-07 kg	2.82E-07 kg
[E1213]	Methyl acrylate[water_river]	2.03E-07 kg	2.16E-07 kg	1.91E-07 kg
[E1214]	Methyl formate[water_river]	1.69E-11 kg	1.78E-11 kg	1.57E-11 kg
[E1215]	Molybdenum[water_ground-]	4.90E-06 kg	5.66E-06 kg	4.40E-06 kg
[E1216]	Molybdenum[water_ground-, long-term]	3.78E-05 kg	4.06E-05 kg	3.33E-05 kg
[E1217]	Molybdenum[water_unspecified]	5.19E-11 kg	4.88E-11 kg	4.78E-11 kg
[E1218]	Molybdenum-99[water_river]	2.43E-06 kBq	1.82E-06 kBq	1.78E-06 kBq
[E1219]	Nickel, ion[water_ground-, long-term]	0.0152 kg	0.00101 kg	0.000674 kg
[E1220]	Nickel, ion[water_lake]	1.45E-12 kg	1.55E-12 kg	1.37E-12 kg
[E1221]	Nickel, ion[water_unspecified]	1.99E-06 kg	1.71E-06 kg	1.64E-06 kg
[E1222]	Niobium-95[water_river]	1.15E-05 kBq	9.76E-06 kBq	8.89E-06 kBq
[E1223]	Nitrate[water_ground-, long-term]	0.198 kg	0.011 kg	0.00551 kg
[E1224]	Nitrite[water_ground-, long-term]	0.099 kg	4.92E-07 kg	4.80E-07 kg
[E1225]	Nitrite[water_ocean]	6.90E-07 kg	6.76E-07 kg	5.70E-07 kg
[E1226]	Nitrite[water_river]	0.00116 kg	5.36E-06 kg	2.26E-06 kg
[E1227]	Nitrobenzene[water_river]	2.78E-10 kg	2.51E-10 kg	2.46E-10 kg
[E1228]	Nitrogen[water_ocean]	3.74E-06 kg	3.59E-06 kg	3.58E-06 kg
[E1229]	Nitrogen, organic bound[water_ground-, long-term]	2.98 kg	1.48E-05 kg	1.44E-05 kg
[E1230]	Oils, unspecified[water_unspecified]	3.67E-05 kg	3.40E-05 kg	3.34E-05 kg
[E1231]	Phenol[water_unspecified]	1.09E-07 kg	1.02E-07 kg	9.50E-08 kg
[E1232]	Phosphate[water_ground-, long-term]	0.0204 kg	0.0227 kg	0.0181 kg
[E1233]	Phosphorus[water_unspecified]	1.08E-07 kg	1.01E-07 kg	9.46E-08 kg
[E1234]	Polonium-210[water_river]	0.000382 kBq	0.000441 kBq	0.000344 kBq
[E1235]	Potassium, ion[water_ground-]	0.000442 kg	0.00051 kg	0.000398 kg
[E1236]	Potassium, ion[water_ground-, long-term]	0.0429 kg	0.0472 kg	0.0381 kg
[E1237]	Potassium-40[water_river]	0.000479 kBq	0.000554 kBq	0.000431 kBq
[E1238]	Protactinium-234[water_river]	0.000822 kBq	0.000771 kBq	0.000665 kBq
[E1239]	Radioactive species, Nuclides, unspecified[water_ocean]	0.266 kBq	0.26 kBq	0.219 kBq
[E1240]	Radioactive species, Nuclides, unspecified[water_river]	0.0012 kBq	0.00117 kBq	0.00105 kBq
[E1241]	Radium-224[water_ocean]	0.0418 kBq	0.0401 kBq	0.0399 kBq
[E1242]	Radium-224[water_river]	0.132 kBq	0.124 kBq	0.123 kBq
[E1243]	Radium-226[water_river]	0.722 kBq	0.677 kBq	0.611 kBq
[E1244]	Radium-226[water_unspecified]	2.99E-06 kBq	2.81E-06 kBq	2.75E-06 kBq
[E1245]	Radium-228[water_ocean]	0.0836 kBq	0.0801 kBq	0.0797 kBq
[E1246]	Radium-228[water_river]	0.263 kBq	0.247 kBq	0.246 kBq
[E1247]	Radium-228[water_unspecified]	4.21E-06 kBq	3.95E-06 kBq	3.87E-06 kBq
[E1248]	Rubidium[water_ocean]	8.36E-06 kg	8.01E-06 kg	7.97E-06 kg
[E1249]	Rubidium[water_river]	2.63E-05 kg	2.47E-05 kg	2.46E-05 kg
[E1250]	Ruthenium-103[water_river]	5.13E-07 kBq	3.84E-07 kBq	3.75E-07 kBq
[E1251]	Scandium[water_ground-]	2.80E-07 kg	3.15E-07 kg	2.48E-07 kg
[E1252]	Scandium[water_ground-, long-term]	2.01E-05 kg	2.13E-05 kg	1.75E-05 kg
[E1253]	Scandium[water_river]	1.78E-07 kg	2.04E-07 kg	1.59E-07 kg
[E1254]	Selenium[water_ground-]	1.08E-06 kg	6.44E-07 kg	5.03E-07 kg
[E1255]	Selenium[water_ground-, long-term]	0.000442 kg	8.66E-05 kg	2.44E-05 kg
[E1256]	Selenium[water_unspecified]	5.02E-12 kg	4.72E-12 kg	4.62E-12 kg
[E1257]	Silicon[water_ground-]	0.000347 kg	0.000401 kg	0.000312 kg
[E1258]	Silicon[water_ground-, long-term]	0.16 kg	0.174 kg	0.136 kg
[E1259]	Silicon[water_ocean]	3.56E-07 kg	3.40E-07 kg	3.40E-07 kg
[E1260]	Silver, ion[water_ground-]	1.63E-08 kg	1.82E-08 kg	1.45E-08 kg
[E1261]	Silver, ion[water_ground-, long-term]	9.66E-07 kg	9.65E-07 kg	8.31E-07 kg
[E1262]	Silver, ion[water_ocean]	5.01E-07 kg	4.81E-07 kg	4.78E-07 kg
[E1263]	Silver, ion[water_unspecified]	4.73E-09 kg	4.45E-09 kg	4.36E-09 kg
[E1264]	Silver-110[water_river]	0.00197 kBq	0.00153 kBq	0.00146 kBq
[E1265]	Sodium, ion[water_ground-]	0.0152 kg	0.00115 kg	0.000901 kg
[E1266]	Sodium, ion[water_ground-, long-term]	1.05 kg	0.119 kg	0.0574 kg
[E1267]	Sodium-24[water_river]	1.84E-05 kBq	1.38E-05 kBq	1.34E-05 kBq
[E1268]	Solids, inorganic[water_ground-]	0.00771 kg	0.00897 kg	0.00695 kg
[E1269]	Strontium[water_ground-]	3.85E-05 kg	2.89E-05 kg	2.34E-05 kg
[E1270]	Strontium[water_ground-, long-term]	0.0642 kg	0.00611 kg	0.00203 kg
[E1271]	Strontium[water_unspecified]	1.23E-07 kg	1.16E-07 kg	1.13E-07 kg
[E1272]	Strontium-89[water_river]	4.32E-05 kBq	3.32E-05 kBq	3.20E-05 kBq
[E1273]	Strontium-90[water_ocean]	0.00566 kBq	0.00555 kBq	0.00468 kBq
[E1274]	Strontium-90[water_river]	0.217 kBq	0.252 kBq	0.195 kBq
[E1275]	Sulfate[water_ground-, long-term]	3.48 kg	0.654 kg	0.482 kg
[E1276]	Sulfate[water_unspecified]	2.77E-06 kg	2.58E-06 kg	2.57E-06 kg
[E1277]	Sulfite[water_river]	1.05E-05 kg	1.20E-05 kg	9.40E-06 kg
[E1278]	Sulfur[water_ocean]	1.22E-05 kg	1.17E-05 kg	1.17E-05 kg
[E1279]	Sulfur[water_unspecified]	5.99E-09 kg	5.63E-09 kg	5.51E-09 kg
[E1280]	TOC, Total Organic Carbon[water_ground-, long-term]	121 kg	0.3 kg	0.00628 kg
[E1281]	TOC, Total Organic Carbon[water_ocean]	0.0335 kg	0.0317 kg	0.0316 kg
[E1282]	Technetium-99m[water_river]	5.59E-05 kBq	4.18E-05 kBq	4.08E-05 kBq
[E1283]	Tellurium-123m[water_river]	8.67E-06 kBq	8.30E-06 kBq	7.09E-06 kBq
[E1284]	Tellurium-132[water_river]	1.41E-07 kBq	1.05E-07 kBq	1.03E-07 kBq
[E1285]	Thallium[water_ground-]	5.69E-08 kg	2.73E-09 kg	2.31E-09 kg
[E1286]	Thallium[water_ground-, long-term]	0.000282 kg	1.12E-05 kg	1.47E-06 kg
[E1287]	Thallium[water_river]	1.03E-07 kg	3.28E-08 kg	1.80E-08 kg
[E1288]	Thallium[water_unspecified]	5.37E-12 kg	5.04E-12 kg	4.94E-12 kg
[E1289]	Thorium-228[water_river]	0.526 kBq	0.494 kBq	0.492 kBq
[E1290]	Thorium-230[water_river]	0.112 kBq	0.105 kBq	0.0907 kBq
[E1291]	Thorium-232[water_river]	8.93E-05 kBq	1.03E-04 kBq	8.04E-05 kBq
[E1292]	Thorium-234[water_river]	0.000822 kBq	0.000771 kBq	0.000665 kBq
[E1293]	Tin, ion[water_ground-]	3.80E-07 kg	1.97E-08 kg	1.71E-08 kg

Appendix C: Results of inventory analysis

[E1294]	Tin, ion[water_ground-, long-term]	0.0184 kg
[E1295]	Tin, ion[water_unspecified]	2.49E-10 kg
[E1296]	Titanium, ion[water_ground-]	0.000117 kg
[E1297]	Titanium, ion[water_ground-, long-term]	0.701 kg
[E1298]	Titanium, ion[water_ocean]	5.53E-08 kg
[E1299]	Titanium, ion[water_river]	0.000179 kg
[E1300]	Titanium, ion[water_unspecified]	3.90E-10 kg
[E1301]	Toluene[water_unspecified]	3.58E-09 kg
[E1302]	Tributyltin compounds[water_ocean]	3.23E-06 kg
[E1303]	Triethylene glycol[water_ocean]	5.76E-06 kg
[E1304]	Tungsten[water_ground-]	6.14E-07 kg
[E1305]	Tungsten[water_ground-, long-term]	1.79E-05 kg
[E1306]	Tungsten[water_river]	1.62E-07 kg
[E1307]	Uranium alpha[water_river]	0.0474 kBq
[E1308]	Uranium-234[water_river]	0.000987 kBq
[E1309]	Uranium-235[water_river]	0.00163 kBq
[E1310]	Uranium-238[water_river]	0.00267 kBq
[E1311]	VOC, volatile organic compounds, unspecified origin[water_ocean]	0.000293 kg
[E1312]	VOC, volatile organic compounds, unspecified origin[water_river]	0.000923 kg
[E1313]	Vanadium, ion[water_ground-]	7.12E-05 kg
[E1314]	Vanadium, ion[water_ground-, long-term]	0.0588 kg
[E1315]	Vanadium, ion[water_unspecified]	6.14E-11 kg
[E1316]	Xylene[water_unspecified]	1.81E-09 kg
[E1317]	Zinc, ion[water_ground-, long-term]	0.326 kg
[E1318]	Zinc, ion[water_lake]	1.05E-12 kg
[E1319]	Zinc, ion[water_unspecified]	2.56E-05 kg
[E1320]	Zinc-65[water_river]	0.000249 kBq
[E1321]	Zirconium-95[water_river]	2.89E-06 kBq
[E1322]	m-Xylene[water_unspecified]	6.84E-11 kg
[E1323]	o-Xylene[water_unspecified]	4.98E-11 kg
[E1324]	t-Butyl methyl ether[water_river]	1.62E-09 kg
[E1325]	Xenon, in air[resource_in air]	4.17E-15 kg
[E1328]	Perlite, in ground[resource_in ground]	-1.47E-15 kg
[E1331]	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.22% in crude ore, in ground[resource_in ground]	1.98E-16 kg
[E1332]	Copper, 0.59% in sulfide, Cu 0.22% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	1.38E-14 kg
[E1333]	Molybdenum, 0.016% in sulfide, Mo 8.2E-3% and Cu 0.27% in crude ore, in ground[resource_in ground]	-2.18E-29 kg
[E1334]	Copper, 0.52% in sulfide, Cu 0.27% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-1.42E-27 kg
[E1336]	Copper, 1.13% in sulfide, Cu 0.76% and Ni 0.76% in crude ore, in ground[resource_in ground]	3.63E-15 kg
[E1338]	Cu, Cu 3.2E+0%, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0% in ore, in ground[resource_in ground]	-1.85E-15 kg
[E1348]	Silver[soil_agricultural]	-6.58E-24 kg
[E1349]	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113[air_unspecified]	1.07E-16 kg
[E1350]	Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124[air_unspecified]	1.07E-16 kg
[E1351]	Heat, waste[air_low population density, long-term]	2.97E-22 MJ
[E1436]	Benzyl alcohol[water_river]	1.37E-26 kg
[E1437]	Cyclohexane[air_high population density]	1.01E-25 kg
[E1439]	Diethylene glycol[air_high population density]	2.58E-22 kg
[E1445]	Diethyl ether[air_high population density]	3.17E-25 kg
[E1461]	Cerium, 24% in bastnasite, 2.4% in crude ore, in ground[resource_in ground]	-1.59E-19 kg
[E1462]	Lanthanum, 7.2% in bastnasite, 0.72% in crude ore, in ground[resource_in ground]	-4.76E-20 kg
[E1463]	Neodymium, 4% in bastnasite, 0.4% in crude ore, in ground[resource_in ground]	-2.62E-20 kg
[E1464]	Praseodymium, 0.42% in bastnasite, 0.042% in crude ore, in ground[resource_in ground]	-2.78E-21 kg
[E1465]	Europium, 0.06% in bastnasite, 0.006% in crude ore, in ground[resource_in ground]	-3.98E-22 kg
[E1466]	Samarium, 0.3% in bastnasite, 0.03% in crude ore, in ground[resource_in ground]	-1.98E-21 kg
[E1467]	Gadolinium, 0.15% in bastnasite, 0.015% in crude ore, in ground[resource_in ground]	-9.93E-22 kg
[E1468]	Suspended solids, unspecified[water_ground-]	2.62E-22 kg
[E1469]	TOC, Total Organic Carbon[water_ground-]	7.85E-26 kg
[E1470]	Thorium-232[water_ground-]	6.62E-22 kBq
[E1592]	Tetramethyl ammonium hydroxide[air_high population density]	1.34E-21 kg
[E1593]	Sulfur hexafluoride[air_high population density]	2.24E-25 kg
[E1594]	Sodium tetrahydroborate[air_high population density]	3.72E-23 kg
[E1595]	Phosphoric acid[air_high population density]	1.01E-25 kg
[E1596]	Nitrogen fluoride[air_high population density]	5.60E-26 kg

[E1294]	Tin, ion[water_ground-, long-term]	0.000754 kg
[E1295]	Tin, ion[water_unspecified]	2.34E-10 kg
[E1296]	Titanium, ion[water_ground-]	2.44E-07 kg
[E1297]	Titanium, ion[water_ground-, long-term]	0.0131 kg
[E1298]	Titanium, ion[water_ocean]	5.29E-08 kg
[E1299]	Titanium, ion[water_river]	1.34E-06 kg
[E1300]	Titanium, ion[water_unspecified]	3.67E-10 kg
[E1301]	Toluene[water_unspecified]	3.36E-09 kg
[E1302]	Tributyltin compounds[water_ocean]	3.05E-06 kg
[E1303]	Triethylene glycol[water_ocean]	5.83E-06 kg
[E1304]	Tungsten[water_ground-]	6.77E-07 kg
[E1305]	Tungsten[water_ground-, long-term]	1.81E-05 kg
[E1306]	Tungsten[water_river]	1.86E-07 kg
[E1307]	Uranium alpha[water_river]	0.0444 kBq
[E1308]	Uranium-234[water_river]	0.000925 kBq
[E1309]	Uranium-235[water_river]	0.00153 kBq
[E1310]	Uranium-238[water_river]	0.00254 kBq
[E1311]	VOC, volatile organic compounds, unspecified origin[water_ocean]	0.00028 kg
[E1312]	VOC, volatile organic compounds, unspecified origin[water_river]	0.000867 kg
[E1313]	Vanadium, ion[water_ground-]	2.81E-07 kg
[E1314]	Vanadium, ion[water_ground-, long-term]	0.012 kg
[E1315]	Vanadium, ion[water_unspecified]	5.77E-11 kg
[E1316]	Xylene[water_unspecified]	1.70E-09 kg
[E1317]	Zinc, ion[water_ground-, long-term]	0.00251 kg
[E1318]	Zinc, ion[water_lake]	1.12E-12 kg
[E1319]	Zinc, ion[water_unspecified]	1.26E-05 kg
[E1320]	Zinc-65[water_river]	1.86E-04 kBq
[E1321]	Zirconium-95[water_river]	2.16E-06 kBq
[E1322]	m-Xylene[water_unspecified]	6.43E-11 kg
[E1323]	o-Xylene[water_unspecified]	4.68E-11 kg
[E1324]	t-Butyl methyl ether[water_river]	1.47E-09 kg
[E1325]	Xenon, in air[resource_in air]	-8.86E-15 kg
[E1328]	Perlite, in ground[resource_in ground]	9.75E-16 kg
[E1331]	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.22% in crude ore, in ground[resource_in ground]	-5.10E-17 kg
[E1332]	Copper, 0.59% in sulfide, Cu 0.22% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-3.57E-15 kg
[E1333]	Molybdenum, 0.016% in sulfide, Mo 8.2E-3% and Cu 0.27% in crude ore, in ground[resource_in ground]	-2.32E-29 kg
[E1334]	Copper, 0.52% in sulfide, Cu 0.27% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-1.51E-27 kg
[E1336]	Copper, 1.13% in sulfide, Cu 0.76% and Ni 0.76% in crude ore, in ground[resource_in ground]	-1.61E-14 kg
[E1338]	Cu, Cu 3.2E+0%, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0% in ore, in ground[resource_in ground]	2.25E-15 kg
[E1348]	Silver[soil_agricultural]	5.80E-25 kg
[E1349]	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113[air_unspecified]	1.22E-16 kg
[E1350]	Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124[air_unspecified]	1.22E-16 kg
[E1351]	Heat, waste[air_low population density, long-term]	8.28E-22 MJ
[E1352]	Oils, biogenic[soil_industrial]	2.94E-39 kg
[E1436]	Benzyl alcohol[water_river]	1.37E-25 kg
[E1437]	Cyclohexane[air_high population density]	1.08E-25 kg
[E1439]	Diethylene glycol[air_high population density]	2.72E-21 kg
[E1445]	Diethyl ether[air_high population density]	3.37E-25 kg
[E1448]	Dimethylamine[air_high population density]	8.60E-26 kg
[E1461]	Cerium, 24% in bastnasite, 2.4% in crude ore, in ground[resource_in ground]	-1.67E-18 kg
[E1462]	Lanthanum, 7.2% in bastnasite, 0.72% in crude ore, in ground[resource_in ground]	-5.02E-19 kg
[E1463]	Neodymium, 4% in bastnasite, 0.4% in crude ore, in ground[resource_in ground]	-2.76E-19 kg
[E1464]	Praseodymium, 0.42% in bastnasite, 0.042% in crude ore, in ground[resource_in ground]	-2.93E-20 kg
[E1465]	Europium, 0.06% in bastnasite, 0.006% in crude ore, in ground[resource_in ground]	-4.20E-21 kg
[E1466]	Samarium, 0.3% in bastnasite, 0.03% in crude ore, in ground[resource_in ground]	-2.09E-20 kg
[E1467]	Gadolinium, 0.15% in bastnasite, 0.015% in crude ore, in ground[resource_in ground]	-1.05E-20 kg
[E1468]	Suspended solids, unspecified[water_ground-]	2.76E-21 kg
[E1469]	TOC, Total Organic Carbon[water_ground-]	8.28E-25 kg
[E1470]	Thorium-232[water_ground-]	6.99E-21 kBq
[E1592]	Tetramethyl ammonium hydroxide[air_high population density]	1.43E-21 kg
[E1593]	Sulfur hexafluoride[air_high population density]	2.38E-25 kg
[E1594]	Sodium tetrahydroborate[air_high population density]	3.96E-23 kg

[E1294]	Tin, ion[water_ground-, long-term]	1.42E-05 kg
[E1295]	Tin, ion[water_unspecified]	2.29E-10 kg
[E1296]	Titanium, ion[water_ground-]	1.92E-07 kg
[E1297]	Titanium, ion[water_ground-, long-term]	0.00091 kg
[E1298]	Titanium, ion[water_ocean]	5.29E-08 kg
[E1299]	Titanium, ion[water_river]	1.02E-06 kg
[E1300]	Titanium, ion[water_unspecified]	3.59E-10 kg
[E1301]	Toluene[water_unspecified]	3.30E-09 kg
[E1302]	Tributyltin compounds[water_ocean]	3.02E-06 kg
[E1303]	Triethylene glycol[water_ocean]	5.95E-06 kg
[E1304]	Tungsten[water_ground-]	5.47E-07 kg
[E1305]	Tungsten[water_ground-, long-term]	1.56E-05 kg
[E1306]	Tungsten[water_river]	1.44E-07 kg
[E1307]	Uranium alpha[water_river]	0.0383 kBq
[E1308]	Uranium-234[water_river]	0.000798 kBq
[E1309]	Uranium-235[water_river]	0.00132 kBq
[E1310]	Uranium-238[water_river]	0.00218 kBq
[E1311]	VOC, volatile organic compounds, unspecified origin[water_ocean]	0.000279 kg
[E1312]	VOC, volatile organic compounds, unspecified origin[water_river]	0.000863 kg
[E1313]	Vanadium, ion[water_ground-]	2.28E-07 kg
[E1314]	Vanadium, ion[water_ground-, long-term]	1.04E-04 kg
[E1315]	Vanadium, ion[water_unspecified]	5.65E-11 kg
[E1316]	Xylene[water_unspecified]	1.66E-09 kg
[E1317]	Zinc, ion[water_ground-, long-term]	0.00209 kg
[E1318]	Zinc, ion[water_lake]	9.91E-13 kg
[E1319]	Zinc, ion[water_unspecified]	1.19E-05 kg
[E1320]	Zinc-65[water_river]	1.82E-04 kBq
[E1321]	Zirconium-95[water_river]	2.11E-06 kBq
[E1322]	m-Xylene[water_unspecified]	6.30E-11 kg
[E1323]	o-Xylene[water_unspecified]	4.59E-11 kg
[E1324]	t-Butyl methyl ether[water_river]	1.46E-09 kg
[E1325]	Xenon, in air[resource_in air]	-3.59E-16 kg
[E1328]	Perlite, in ground[resource_in ground]	4.40E-15 kg
[E1331]	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.22% in crude ore, in ground[resource_in ground]	3.21E-18 kg
[E1332]	Copper, 0.59% in sulfide, Cu 0.22% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	2.25E-16 kg
[E1333]	Molybdenum, 0.016% in sulfide, Mo 8.2E-3% and Cu 0.27% in crude ore, in ground[resource_in ground]	-2.05E-29 kg
[E1334]	Copper, 0.52% in sulfide, Cu 0.27% and Mo 8.2E-3% in crude ore, in ground[resource_in ground]	-1.34E-27 kg
[E1336]	Copper, 1.13% in sulfide, Cu 0.76% and Ni 0.76% in crude ore, in ground[resource_in ground]	-2.59E-14 kg
[E1338]	Cu, Cu 3.2E+0%, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0% in ore, in ground[resource_in ground]	3.00E-15 kg
[E1348]	Silver[soil_agricultural]	1.10E-23 kg
[E1349]	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113[air_unspecified]	8.55E-17 kg
[E1350]	Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124[air_unspecified]	8.55E-17 kg
[E1351]	Heat, waste[air_low population density, long-term]	5.11E-22 MJ
[E1436]	Benzyl alcohol[water_river]	1.23E-25 kg
[E1437]	Cyclohexane[air_high population density]	9.52E-26 kg
[E1439]	Diethylene glycol[air_high population density]	5.44E-22 kg
[E1445]	Diethyl ether[air_high population density]	2.98E-25 kg
[E1461]	Cerium, 24% in bastnasite, 2.4% in crude ore, in ground[resource_in ground]	-3.35E-19 kg
[E1462]	Lanthanum, 7.2% in bastnasite, 0.72% in crude ore, in ground[resource_in ground]	-1.00E-19 kg
[E1463]	Neodymium, 4% in bastnasite, 0.4% in crude ore, in ground[resource_in ground]	-5.52E-20 kg
[E1464]	Praseodymium, 0.42% in bastnasite, 0.042% in crude ore, in ground[resource_in ground]	-5.86E-21 kg
[E1465]	Europium, 0.06% in bastnasite, 0.006% in crude ore, in ground[resource_in ground]	-8.39E-22 kg
[E1466]	Samarium, 0.3% in bastnasite, 0.03% in crude ore, in ground[resource_in ground]	-4.18E-21 kg
[E1467]	Gadolinium, 0.15% in bastnasite, 0.015% in crude ore, in ground[resource_in ground]	-2.09E-21 kg
[E1468]	Suspended solids, unspecified[water_ground-]	5.52E-22 kg
[E1469]	TOC, Total Organic Carbon[water_ground-]	1.66E-25 kg
[E1470]	Thorium-232[water_ground-]	1.40E-21 kBq
[E1592]	Tetramethyl ammonium hydroxide[air_high population density]	1.26E-21 kg
[E1593]	Sulfur hexafluoride[air_high population density]	2.10E-25 kg
[E1594]	Sodium tetrahydroborate[air_high population density]	3.49E-23 kg
[E1595]	Phosphoric acid[air_high population density]	9.52E-26 kg
[E1596]	Nitrogen fluoride[air_high population density]	5.26E-26 kg

Appendix C: Results of inventory analysis

[E1597]	Boric acid[air_high population density]	2.86E-27	kg
[E1598]	Ethane, 1,1,1-trichloro-, HCFC-140[water_river]	4.78E-29	kg
[E1611]	Acetone[air_unspecified]	2.24E-24	kg
[E1612]	Phosphorus trichloride[air_high population density]	1.92E-23	kg
[E1647]	Nitrite[water_ground-]	2.41E-04	kg

[E1595]	Phosphoric acid[air_high population density]	1.08E-25	kg
[E1596]	Nitrogen fluoride[air_high population density]	5.96E-26	kg
[E1597]	Boric acid[air_high population density]	3.04E-27	kg
[E1598]	Ethane, 1,1,1-trichloro-, HCFC-140[water_river]	5.09E-29	kg
[E1611]	Acetone[air_unspecified]	2.38E-24	kg
[E1612]	Phosphorus trichloride[air_high population density]	2.04E-23	kg

[E1597]	Boric acid[air_high population density]	2.69E-27	kg
[E1598]	Ethane, 1,1,1-trichloro-, HCFC-140[water_river]	4.49E-29	kg
[E1611]	Acetone[air_unspecified]	2.10E-24	kg
[E1612]	Phosphorus trichloride[air_high population density]	1.81E-23	kg

Appendix D: Procedure to modify and withdraw information from Ecoinvent files

Manual to modify the amount of landfill gas captured and burned and the landfill gas composition - in the short-term

1 Download the following calculation tools Excel spreadsheets from http://www.ecoinvent.org/
  a 13_MSWIv2 Calculation Tool for Municipal Solid Waste Incinerator MSWI
  b 13_MSWLFv2 Calculation Tool for waste disposal in Municipal Sanitary Waste Landfill MSWLF

2 Run both at the same time. Documents are cross-linked. Be sure not to save the original sheets under different names.
  Do not update links to other sheets. Choose 'No' in the dialog box.

3 In document "13_MSWIv2" - which contains the waste definitions
  a Go to sheet "waste input"
    In cell "B4" select the type of disposal you want. In this case, select "R" - municipal waste landfill

  b Go to cell "A78" and choose the type of waste you are treating
    The types of waste already existing are listed in column A, from A81 till A174
    For this case, put "9" for "plastics, mixture, 15.3% water"

4 In document "13_MSWLFv2" - acronym for 'municipal solid waste landfill'
  a Unhide the sheet "air & energy"
  b Go to cell "D7" and change the percentage of "landfill gas captured". Number from 0% till 100%
  c The amount of gas "emitted directly" in cell "D9" is automatically calculated
  d The new emissions are shown in P14:V64

Manual to calculate the leachate composition - in the short-term - landfill disposal

1 Download the following calculation tools Excel spreadsheets from http://www.ecoinvent.org/
  a 13_MSWIv2 Calculation Tool for Municipal Solid Waste Incinerator MSWI
  b 13_MSWLFv2 Calculation Tool for waste disposal in Municipal Sanitary Waste Landfill MSWLF

2 Run both at the same time. Documents are cross-linked. Be sure not to save the original sheets under different names.
  Do not update links to other sheets. Choose 'No' in the dialog box.

3 In document "13_MSWIv2" - which contains the waste definitions
  a Go to sheet "waste input"
    In cell "B4" select the type of disposal you want. In this case, select "R" - municipal waste landfill

  b Go to cell "A78" and choose the type of waste you are treating
    The types of waste already existing are listed in column A, from A81 till A174
    For plastic waste, the numbers related to different types of plastic waste are listed from "waste nr 9" until "waste nr 15"
    For this case, put "9" for "plastics, mixture, 15.3% water" in cell "A78"

4 In document "13_MSWLFv2" - acronym for 'municipal solid waste landfill'
  a Unhide the sheet "leachate treat"
    This sheet shows the characteristics of the wastewater under treatment AND the characteristics of the leachate prior treatment
    The calculations are based in the assumptions of "Release short-term leachate (to WWTP)"

  b In rows 91 and 92, the amounts of generated leachate in volume, and the compounds of this leachate are available, for a short-time period of 100yr
    The quantities are expresed in kg/kg of waste disposed in landfill
    The amounts are related to the type of waste selected in "13_MSWIv2", in this example, "9" - "plastics, mixture, 15.3% water"

Appendix D: Procedure to modify and withdraw information from Ecoinvent files

Manual to calculate the amount of electricity that is generated during municipal incineration

1 Download the following calculation tools Excel spreadsheets from http://www.ecoinvent.org/
   a 13_MSWIv2 Calculation Tool for Municipal Solid Waste Incinerator MSWI

2 Documents are cross-linked. Be sure not to save the original sheets under different names.
   Do not update links to other sheets. Choose 'No' in the dialog box.
3 In document "13_MSWIv2" - which contains the waste definitions
   a Go to sheet "waste input"
   In cell "B4" select the type of disposal you want. In this case, select "M" - Municipal solid waste incinerator

   b Go to cell "A78" and choose the type of waste you are treating
   The types of waste already existing are listed in column A, from A81 till A174
   For plastic waste, the numbers related to different types of plastic waste are listed from "waste nr 9" until "waste nr 15"
   For this case, put "9" for "plastics, mixture, 15.3% water" in cell "A78"

   c Unhide the sheet "energy" where calculation of energy balance, waste heat, generated energy information is available

   d The "energy" sheet contain information related to:
   Energy content in waste
   Energy conversion in MSWI
   Internal consumption during incineration
   Net energy production in MSWI

   e In section "Net energy production in MSWI", the electric energy available for use is shown

Manual to calculate separately the short-term impacts of sanitary landfill

1 Download the following calculation tools Excel spreadsheets from http://www.ecoinvent.org/
   a 13_MSWIv2 Calculation Tool for Municipal Solid Waste Incinerator MSWI
   b 13_MSWLFv2 Calculation Tool for waste disposal in Municipal Sanitary Waste Landfill MSWLF

2 Run both at the same time. Documents are cross-linked. Be sure not to save the original sheets under different
   Do not update links to other sheets. Choose 'No' in the dialog box.
3 In document "13_MSWIv2" - which contains the waste definitions
   a Go to sheet "waste input"
   In cell "B4" select the type of disposal you want. In this case, select "R" - municipal waste landfill

   b Go to cell "A78" and choose the type of waste you are treating
   The types of waste already existing are listed in column A, from A81 till A174
   For this case, put "9" for "plastics, mixture, 15.3% water"

4 In document "13_MSWLFv2" - acronym for 'municipal solid waste landfill'
   a Unhide the sheet "air & energy"
   b Go to cell "D7" and change the percentage of "landfill gas captured". Number from 0% till 100%
   c Go to sheet "MSWLF calculation"
   In column AD, change the values from AD20 till AD61 to 0
   Column AD summarizes the assumed impacts for the long-term, turning them to 0, allows to calculate only the impacts generated by the shor-term
   d Go to sheet "X-Exchange"
   In this sheet, the emissions from sanitary landfill without considering the long-term are shown

Appendix E: Contribution Analysis

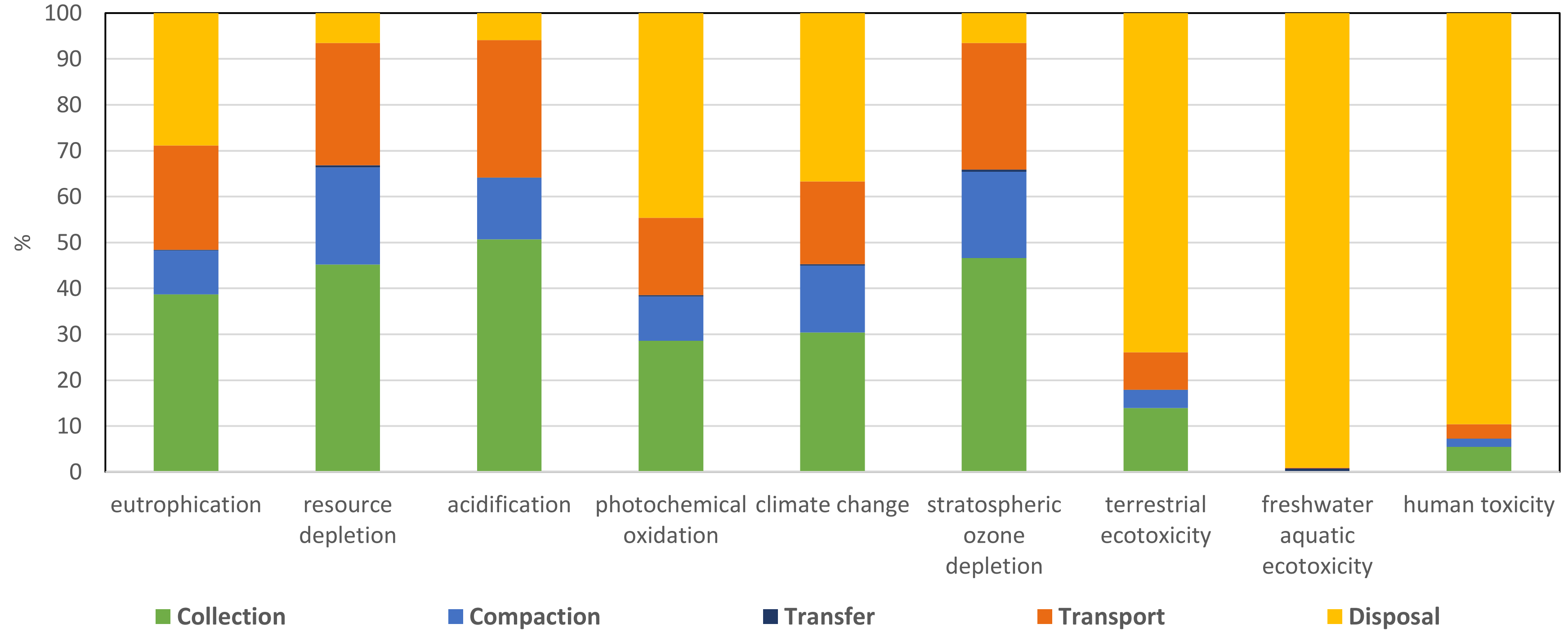
Scenario SC1

Label	Name	[A1] Output of [W4088] SC1 generated MPW	[A4] Output of [W4089] SC1 collected MPW	[A5] Output of [W4090] SC1 compacted MPW	[A6] Output of [W4091] SC1 transfered MPW	[A14] Output of [G185] transport, municipal waste collection, lorry 21t[CH]
[C3]	eutrophication	0.292	0.179	0.151	0.0842	0.0664
[C5]	resource depletion	1.57	0.86	0.528	0.102	0.419
[C14]	acidification	0.964	0.475	0.346	0.0564	0.289
[C17]	photochemical oxidation	0.0664	0.0474	0.041	0.0296	0.0112
[C22]	climate change	365	254	201	134	65.6
[C46]	stratospheric ozone depletion	3.56E-05	1.90E-05	1.23E-05	2.33E-06	9.81E-06
[C29]	terrestrial ecotoxicity	0.797	0.686	0.655	0.589	0.0654
[C38]	freshwater aquatic ecotoxicity	1.10E+03	1.10E+03	1.10E+03	1.09E+03	1.92
[C50]	human toxicity	441	417	409	395	13.9

		Collection	Compaction	Transfer	Transport	Disposal	Total
[C3]	eutrophication	0.11	0.028	0.0004	0.066	0.084	0.292
[C5]	resource depletion	0.71	0.33	0.007	0.42	0.102	1.57
[C14]	acidification	0.49	0.13	0.0006	0.29	0.06	0.96
[C17]	photochemical oxidation	0.02	0.01	0.0002	0.01	0.03	0.066
[C22]	climate change	111	53	1.4	65.6	134	365
[C46]	stratospheric ozone depletion	1.7E-05	6.7E-06	1.6E-07	9.8E-06	2.3E-06	3.6E-05
[C29]	terrestrial ecotoxicity	0.11	0.031	0.0006	0.065	0.589	0.797
[C38]	freshwater aquatic ecotoxicity	0	0	8.08	1.92	1090	1100
[C50]	human toxicity	24	8	0.1	13.9	395	441

		Collection %	Compaction %	Transfer %	Transport %	Disposal %	Total %
[C3]	eutrophication	38.7	9.6	0.1	22.7	28.8	100
[C5]	resource depletion	45.2	21.1	0.4	26.7	6.5	100.0
[C14]	acidification	50.7	13.4	0.1	30.0	5.9	100
[C17]	photochemical oxidation	28.6	9.6	0.3	16.9	44.6	100
[C22]	climate change	30.4	14.5	0.4	18.0	36.7	100
[C46]	stratospheric ozone depletion	46.6	18.8	0.4	27.6	6.5	100
[C29]	terrestrial ecotoxicity	13.9	3.9	0.1	8.2	73.9	100
[C38]	freshwater aquatic ecotoxicity	0.0	0.0	0.7	0.2	99.1	100
[C50]	human toxicity	5.4	1.8	0.0	3.2	89.6	100

Appendix E: Contribution Analysis



Contribution of each stage per impact category for SC1

Appendix E: Contribution Analysis

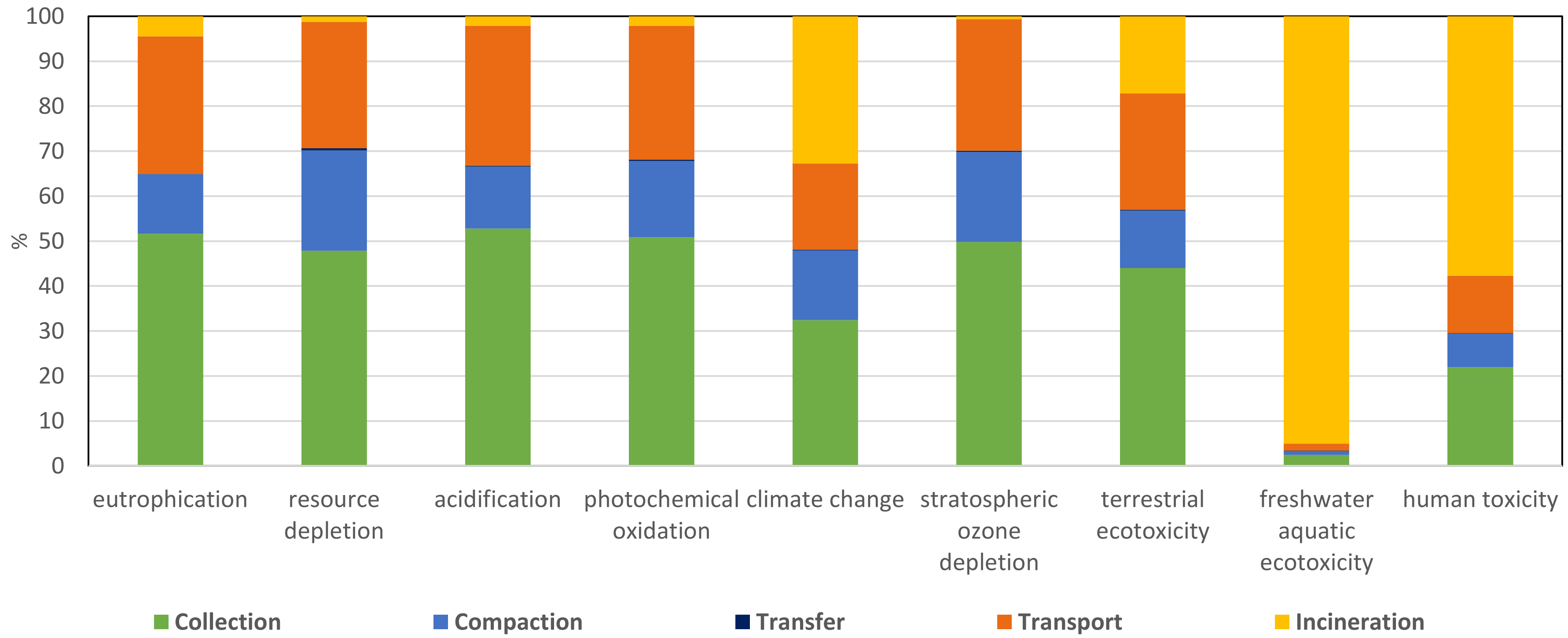
Scenario SC2

Label	Name	[A2] Output of [W4094] SC2 generated MPW	[A7] Output of [W4096] SC2 collected MPW	[A8] Output of [W4097] SC2 compacted MPW	[A9] Output of [W4098] SC2 transfered MPW	[A14] Output of [G185] transport, municipal waste collection, lorry 21t[CH]
[C3]	eutrophication	0.217	0.105	0.0763	0.00971	0.0664
[C5]	resource depletion	1.49	0.777	0.444	0.0181	0.419
[C14]	acidification	0.928	0.438	0.31	0.0199	0.289
[C17]	photochemical oxidation	0.0376	0.0185	0.0121	0.000791	0.0112
[C22]	climate change	342	231	178	112	65.6
[C46]	stratospheric ozone depletion	3.35E-05	1.68E-05	1.01E-05	2.08E-07	9.81E-06
[C29]	terrestrial ecotoxicity	0.252	0.141	0.109	0.0432	0.0654
[C38]	freshwater aquatic ecotoxicity	121	118	117	115	1.92
[C50]	human toxicity	109	85.1	76.9	62.9	13.9

		Collection	Compaction	Transfer	Transport	Incineration	Total
[C3]	eutrophication	0.11	0.03	0.0002	0.07	0.01	0.217
[C5]	resource depletion	0.71	0.33	0.007	0.42	0.02	1.49
[C14]	acidification	0.49	0.13	0.001	0.29	0.02	0.928
[C17]	photochemical oxidation	1.9E-02	6.4E-03	1.1E-04	1.1E-02	7.9E-04	3.8E-02
[C22]	climate change	111	53	0.4	65.6	112	342
[C46]	stratospheric ozone depletion	1.7E-05	6.7E-06	8.2E-08	9.8E-06	2.1E-07	3.4E-05
[C29]	terrestrial ecotoxicity	0.11	0.03	0.0004	0.065	0.043	0.252
[C38]	freshwater aquatic ecotoxicity	3	1	0.08	1.9	115	121
[C50]	human toxicity	23.9	8.2	0.1	13.9	62.9	109

		Collection %	Compaction %	Transfer %	Transport %	Incineration %	Total %
[C3]	eutrophication	51.6	13.2	0.1	30.6	4.5	100
[C5]	resource depletion	47.9	22.3	0.5	28.1	1.2	100
[C14]	acidification	52.8	13.8	0.1	31.1	2.1	100
[C17]	photochemical oxidation	50.8	17.0	0.3	29.8	2.1	100
[C22]	climate change	32.5	15.5	0.1	19.2	32.7	100
[C46]	stratospheric ozone depletion	49.9	20.0	0.2	29.3	0.6	100
[C29]	terrestrial ecotoxicity	44.0	12.7	0.2	26.0	17.1	100
[C38]	freshwater aquatic ecotoxicity	2.5	0.8	0.1	1.6	95.0	100
[C50]	human toxicity	21.9	7.5	0.1	12.8	57.7	100

Appendix E: Contribution Analysis



Contribution of each stage per impact category for SC2

Appendix E: Contribution Analysis

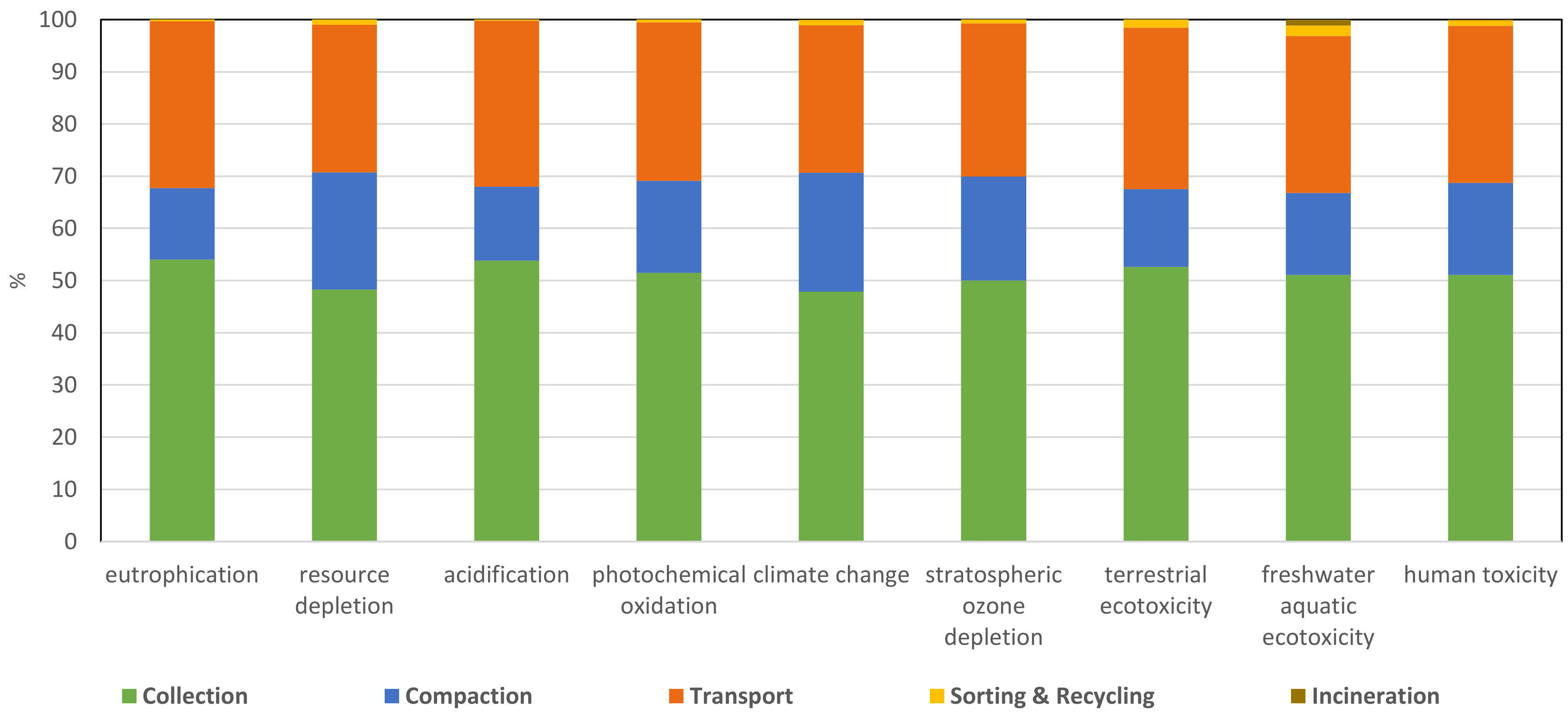
Scenario SC3

Label	Name	[A3] Output of [W4099] SC3 generated MPW	[A10] Output of [W4101] SC3 collected MPW	[A11] Output of [W4102] SC3 compacted MPW	[A14] Output of [G185] transport, municipal waste collection, lorry 21t[CH]	[A12] Output of [W4105] SC3 unsorted plastics from NIR and manual separation	[A13] Output of [W4112] SC3 losses from mechanical recycling
[C3]	eutrophication	0.208	0.0956	0.000705	0.0664	5.06E-06	9.60E-06
[C5]	resource depletion	1.48	0.766	0.0147	0.419	7.29E-06	1.38E-05
[C14]	acidification	0.909	0.42	0.00215	0.289	1.12E-05	2.13E-05
[C17]	photochemical oxidation	0.0369	0.0179	0.000202	0.0112	3.74E-07	7.08E-07
[C22]	climate change	232	121	2.46	65.6	0.0617	0.117
[C46]	stratospheric ozone depletion	3.34E-05	1.67E-05	2.42E-07	9.81E-06	9.24E-11	1.75E-10
[C29]	terrestrial ecotoxicity	0.211	0.1	0.00319	0.0654	1.44E-05	2.73E-05
[C38]	freshwater aquatic ecotoxicity	6.38	3.12	0.199	1.92	0.0246	0.0467
[C50]	human toxicity	46.2	22.6	0.555	13.9	0.0175	0.0332

		Collection	Compaction	Transport	Sorting&Recycling	Incineration	Total
[C3]	eutrophication	1.1E-01	2.8E-02	6.6E-02	6.9E-04	1.5E-05	2.1E-01
[C5]	resource depletion	7.1E-01	3.3E-01	4.2E-01	1.5E-02	2.1E-05	1.48
[C14]	acidification	4.9E-01	1.3E-01	2.9E-01	2.1E-03	3.3E-05	9.1E-01
[C17]	photochemical oxidation	1.9E-02	6.5E-03	1.1E-02	2.0E-04	1.1E-06	3.7E-02
[C22]	climate change	111	52.9	65.6	2.28	0.18	232
[C46]	stratospheric ozone depletion	1.7E-05	6.6E-06	9.8E-06	2.4E-07	2.7E-10	3.34E-05
[C29]	terrestrial ecotoxicity	1.1E-01	3.1E-02	6.5E-02	3.1E-03	4.2E-05	2.1E-01
[C38]	freshwater aquatic ecotoxicity	3.26	1.00	1.92	0.13	0.07	6.38
[C50]	human toxicity	23.6	8.1	13.9	0.50	0.05	46.2

		Collection %	Compaction %	Transport %	Sorting & Recycling %	Incineration %	Total %
[C3]	eutrophication	54.0	13.7	31.9	0.3	0.0	100
[C5]	resource depletion	48.2	22.5	28.3	1.0	0.0	100
[C14]	acidification	53.8	14.2	31.8	0.2	0.0	100
[C17]	photochemical oxidation	51.5	17.6	30.4	0.5	0.0	100
[C22]	climate change	47.8	22.8	28.3	1.0	0.1	100
[C46]	stratospheric ozone depletion	50.0	19.9	29.4	0.7	0.0	100
[C29]	terrestrial ecotoxicity	52.6	14.9	31.0	1.5	0.0	100
[C38]	freshwater aquatic ecotoxicity	51.1	15.7	30.1	2.0	1.1	100
[C50]	human toxicity	51.1	17.6	30.1	1.1	0.1	100

Appendix E: Contribution Analysis



Contribution of each stage per impact category for SC3

Appendix F: Sensitivity analysis

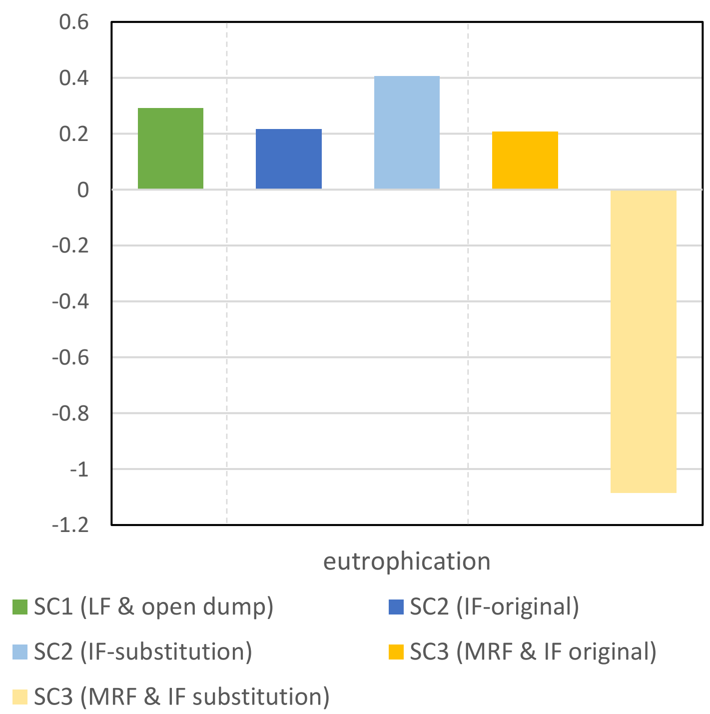
Sensitivity of the selected allocation method

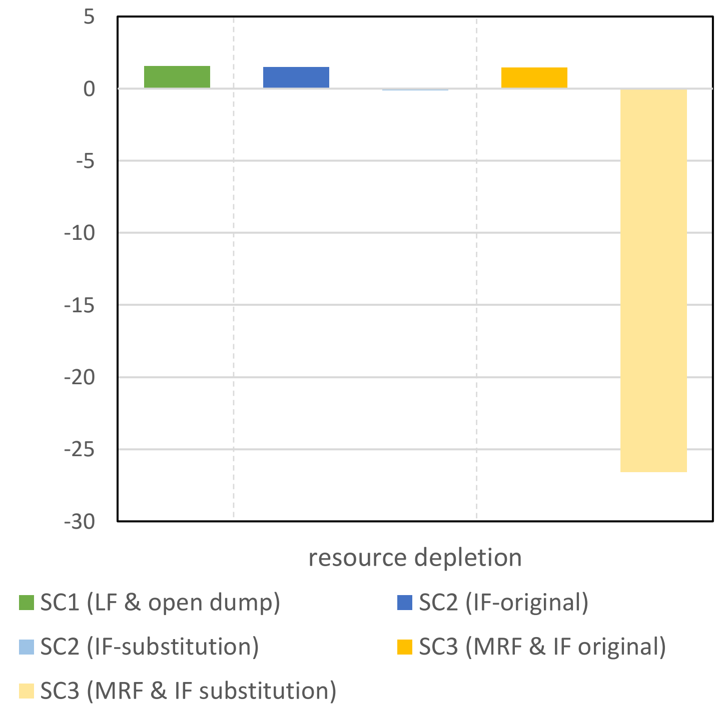
Solving multifunctionality by substitution - Energy mix: 50/50 hydropower and thermoelectric

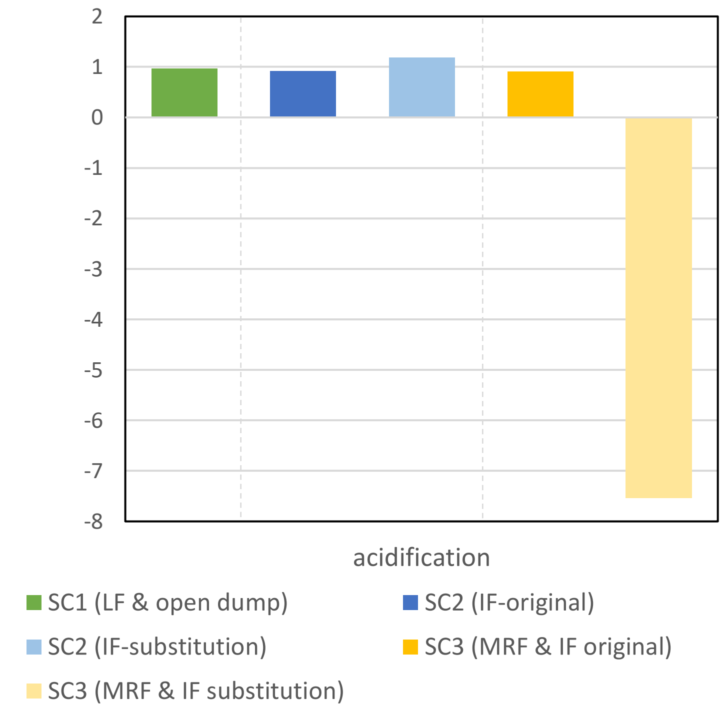
Label	Name	SC1 (LF & open dump)	SC2 (IF)	SC3 (MRF & IF)	SC2 Avoided energy	SC3 Avoided plastic	SC3 Avoided Energy	Unit
[C3]	eutrophication	0.292	0.439	0.299	0.0318	1.38	0.004	kg PO4-Eq
[C5]	resource depletion	1.57	1.9	2.85	2.03	29.2	0.255	kg antimony-Eq
[C14]	acidification	0.964	1.38	1.16	0.193	8.68	0.0243	kg SO2-Eq
[C17]	photochemical oxidation	0.0664	0.0556	0.0571	0.0245	0.501	0.00308	kg ethylene-Eq
[C22]	climate change	365	2900	779	326	2230	40.9	kg CO2-Eq
[C46]	stratospheric ozone depletion	3.56E-05	3.82E-05	5.58E-05	3.43E-05	3.25E-05	4.31E-06	kg CFC-11-Eq
[C29]	terrestrial ecotoxicity	0.797	1.24	0.576	0.0771	3.97	0.0097	kg 1,4-DCB-Eq
[C38]	freshwater aquatic ecotoxicity	1100	2750	154	2.91	207	0.366	kg 1,4-DCB-Eq
[C50]	human toxicity	441	1550	188	32.6	669	4.1	kg 1,4-DCB-Eq

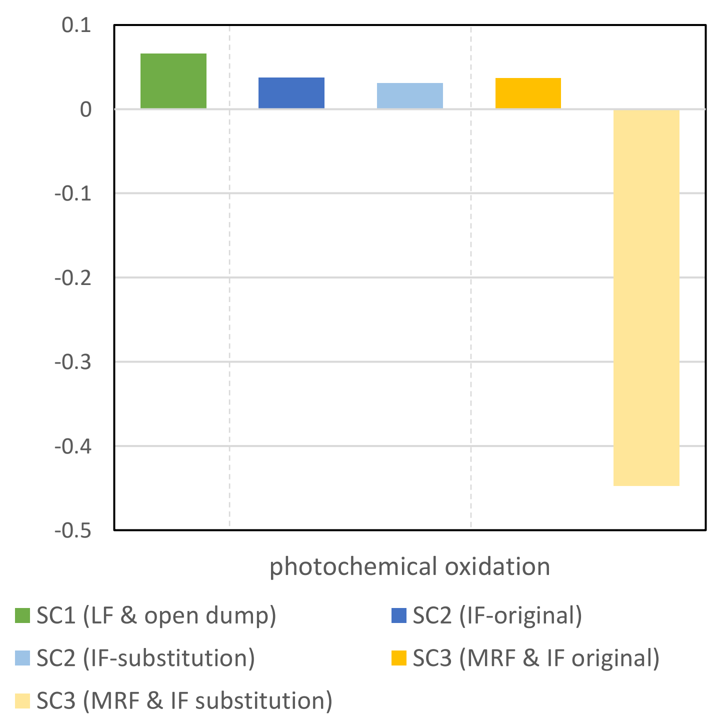
Label	Name	SC1 (LF & open dump)	SC2 (IF-original)	SC2 (IF-substitution)	SC3 (MRF & IF original)	SC3 (MRF & IF substitution)	Unit
[C3]	eutrophication	0.292	0.217	0.4072	0.208	-1.085	kg PO4-Eq
[C5]	resource depletion	1.57	1.49	-0.13	1.48	-26.61	kg antimony-Eq
[C14]	acidification	0.964	0.928	1.187	0.909	-7.54	kg SO2-Eq
[C17]	photochemical oxidation	0.0664	0.0376	0.0311	0.0369	-0.45	kg ethylene-Eq
[C22]	climate change	365	342	2574	232	-1491.9	kg CO2-Eq
[C46]	stratospheric ozone depletion	3.56E-05	3.35E-05	3.90E-06	3.34E-05	1.90E-05	kg CFC-11-Eq
[C29]	terrestrial ecotoxicity	0.797	0.252	1.1629	0.211	-3.40	kg 1,4-DCB-Eq
[C38]	freshwater aquatic ecotoxicity	1100	121	2747.09	6.38	-53.4	kg 1,4-DCB-Eq
[C50]	human toxicity	441	109	1517.4	46.2	-485.1	kg 1,4-DCB-Eq

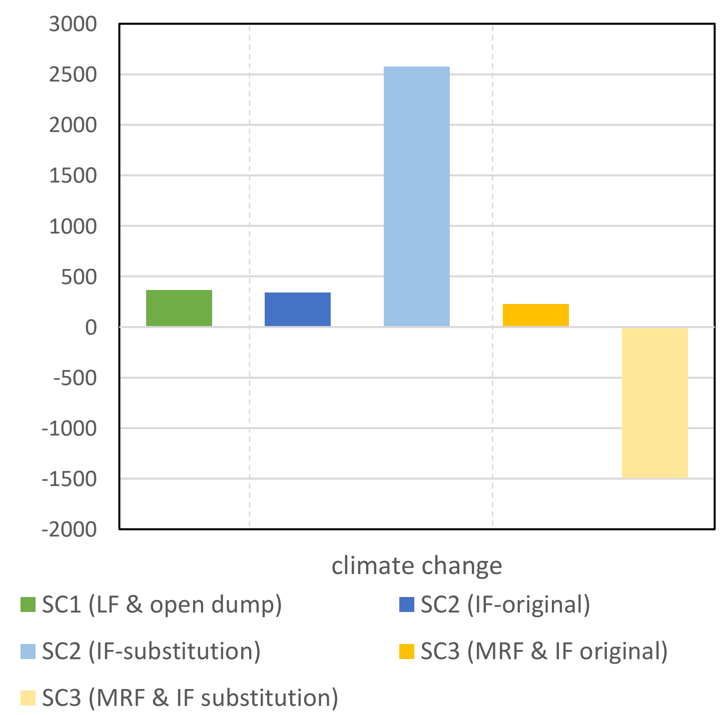
Appendix F: Sensitivity analysis

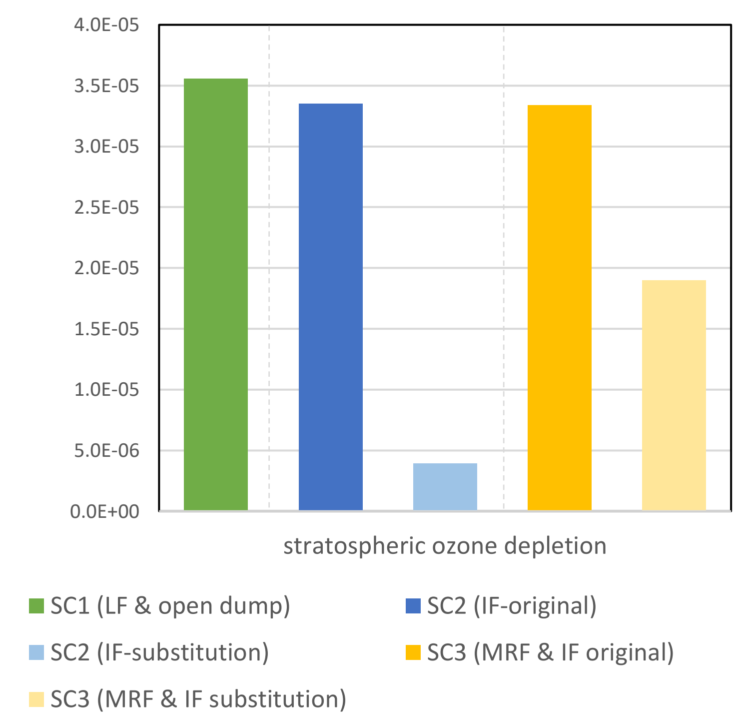












Appendix F: Sensitivity analysis

Sensitivity of the selected type of energy mix

Solving multifunctionality by substitution - Energy mix: 100% hard coal

Label	Name	SC1 (LF & open dump)	SC2 (IF)	SC3 (MRF & IF)	Unit
[C3]	eutrophication	0.292	-1.961	-1.382	kg PO4-Eq
[C5]	resource depletion	1.57	-7.39	-27.52	kg antimony-Eq
[C14]	acidification	0.964	-11.42	-9.13	kg SO2-Eq
[C17]	photochemical oxidation	0.0664	-0.3934	-0.5004	kg ethylene-Eq
[C22]	climate change	365	1670	-1605	kg CO2-Eq
[C46]	stratospheric ozone depletion	3.56E-05	3.21E-05	2.25E-05	kg CFC-11-Eq
[C29]	terrestrial ecotoxicity	0.797	-1.02	-3.678	kg 1,4-DCB-Eq
[C38]	freshwater aquatic ecotoxicity	1100	2361	-101.9	kg 1,4-DCB-Eq
[C50]	human toxicity	441	1073	-541	kg 1,4-DCB-Eq

Comparison of avoided energy mix: hydropower-thermoelectric vs hard coal

Label	Name	[A4] Output of [G4114] SC2 Avoided energy mix	[A5] Output of [G4115] SC2 Avoided energy from coal	[A7] Output of [G4123] SC3 Avoided energy production	[A8] Output of [G4118] SC3 Avoided energy from coal	Unit
[C3]	eutrophication	0.0318	2.4	0.004	0.301	kg PO4-Eq
[C5]	resource depletion	2.03	9.29	0.255	1.17	kg antimony-Eq
[C14]	acidification	0.193	12.8	0.0243	1.61	kg SO2-Eq
[C17]	photochemical oxidation	0.0245	0.449	0.00308	0.0565	kg ethylene-Eq
[C22]	climate change	326	1230	40.9	154	kg CO2-Eq
[C46]	stratospheric ozone depletion	3.43E-05	6.10E-06	4.31E-06	7.67E-07	kg CFC-11-Eq
[C29]	terrestrial ecotoxicity	0.0771	2.26	0.0097	0.284	kg 1,4-DCB-Eq
[C38]	freshwater aquatic ecotoxicity	2.91	389	0.366	48.9	kg 1,4-DCB-Eq
[C50]	human toxicity	32.6	477	4.1	60	kg 1,4-DCB-Eq

Appendix F: Sensitivity analysis

Sensitivity of the selected replacement ratio

Replaced virgin plastics 1:1 vs 1:0.5 (by changing plastic pellet price by half) - Using economic allocation method

Label	**Name**	**SC1 (LF & open dump)**	**SC2 (IF)**	**SC3 (1:1)**	**SC3 (1:0.5)**	**Unit**
[C3]	eutrophication	0.292	0.217	0.208	0.209	kg PO4-Eq
[C5]	resource depletion	1.57	1.49	1.48	1.49	kg antimony-Eq
[C14]	acidification	0.964	0.928	0.909	0.911	kg SO2-Eq
[C17]	photochemical oxidation	0.0664	0.0376	0.0369	0.0371	kg ethylene-Eq
[C22]	climate change	365	342	232	234	kg CO2-Eq
[C46]	stratospheric ozone depletion	3.56E-05	3.35E-05	3.34E-05	3.36E-05	kg CFC-11-Eq
[C29]	terrestrial ecotoxicity	0.797	0.252	0.211	0.214	kg 1,4-DCB-Eq
[C38]	freshwater aquatic ecotoxicity	1100	121	6.38	6.57	kg 1,4-DCB-Eq
[C50]	human toxicity	441	109	46.2	46.7	kg 1,4-DCB-Eq

Replaced virgin plastics 1:1 vs 1:0.5 (by changing avoided plastic pellets by half) - Using substitution method

Label	Name	**SC1 (LF & open dump)**	**SC2 (IF)**	**SC3 (MRF & IF)**	**SC2 Avoided energy**	**SC3 Avoided Energy**	**SC3 Avoided plastic (1:1)**	**SC3 Avoided plastic (1:0.5)**
[C3]	eutrophication	0.292	0.439	0.299	0.0318	0.004	1.38	0.688
[C5]	resource depletion	1.57	1.9	2.85	2.03	0.255	29.2	14.6
[C14]	acidification	0.964	1.38	1.16	0.193	0.0243	8.68	4.34
[C17]	photochemical oxidation	0.0664	0.0556	0.0571	0.0245	0.00308	0.501	0.25
[C22]	climate change	365	2900	779	326	40.9	2230	1120
[C46]	stratospheric ozone depletion	3.56E-05	3.82E-05	5.58E-05	3.43E-05	4.31E-06	3.25E-05	1.63E-05
[C29]	terrestrial ecotoxicity	0.797	1.24	0.576	0.0771	0.0097	3.97	1.98
[C38]	freshwater aquatic ecotoxicity	1100	2750	154	2.91	0.366	207	104
[C50]	human toxicity	441	1550	188	32.6	4.1	669	334

		SC1 (LF & open dump)	**SC2 (IF-substitution)**	**SC3 (1:1)**	**SC3 (1:0.5)**	**% reduction between SC3 (1:1) and SC3 (1:0.5)**
[C3]	eutrophication	0.292	0.4072	-1.09	-0.393	36%
[C5]	resource depletion	1.57	-0.13	-26.61	-12.005	45%
[C14]	acidification	0.964	1.187	-7.54	-3.2043	42%
[C17]	photochemical oxidation	0.0664	0.0311	-0.45	-0.19598	44%
[C22]	climate change	365	2574	-1491.9	-381.9	26%
[C46]	stratospheric ozone depletion	3.56E-05	3.90E-06	1.90E-05	3.52E-05	185%
[C29]	terrestrial ecotoxicity	0.797	1.1629	-3.4037	-1.4137	42%
[C38]	freshwater aquatic ecotoxicity	1100	2747.09	-53.366	49.634	-93%
[C50]	human toxicity	441	1517.4	-485.1	-150.1	31%

Appendix F: Sensitivity analysis

Sensitivity of the assumed transport distances in SC3

Evaluating the increase of transport distances from 50km to 60km and 70km

Label	Name	SC1 (75% LF 25% open dump)	SC2 (100% IF)	SC3 (85.5% MRF & 14.5% IF)	SC3 (+10km)	SC3 (+20km)	Unit
[C3]	eutrophication	0.292	0.217	0.208	0.221	0.235	kg PO4-Eq
[C5]	resource depletion	1.57	1.49	1.48	1.56	1.64	kg antimony-Eq
[C14]	acidification	0.964	0.928	0.909	0.967	1.02	kg SO2-Eq
[C17]	photochemical oxidation	0.0664	0.0376	0.0369	0.0391	0.0414	kg ethylene-Eq
[C22]	climate change	365	342	232	245	258	kg CO2-Eq
[C46]	stratospheric ozone depletion	3.56E-05	3.35E-05	3.34E-05	3.53E-05	3.73E-05	kg CFC-11-Eq
[C29]	terrestrial ecotoxicity	0.797	0.252	0.211	0.224	0.237	kg 1,4-DCB-Eq
[C38]	freshwater aquatic ecotoxicity	1100	121	6.38	6.77	7.15	kg 1,4-DCB-Eq
[C50]	human toxicity	441	109	46.2	49	51.8	kg 1,4-DCB-Eq

Sensitivity of emissions from landfills in the long-term vs short-term

Evaluating 750kg going to landfill in the short-term and long-term

Label	Name	SC1 (75% LF 25% open dump)	Total impact of sanitary landfill (75% of MPW in SC1)	Impacts from short-term	Impacts from long-term	% short-term of total impact of landfill	% long-term to total impact of landfill	% short-term of SC1	% long-term of SC1
[C3]	eutrophication	0.292	0.0841	0.055	0.0291	65%	35%	19%	10%
[C5]	resource depletion	1.57	0.102	0.102	0	100%	0%	6%	0%
[C14]	acidification	0.964	0.0558	0.0558	0	100%	0%	6%	0%
[C17]	photochemical oxidation	0.0664	0.0227	0.013	0.0097	57%	43%	20%	15%
[C22]	climate change	365	103	67.3	35.7	65%	35%	18%	10%
[C46]	stratospheric ozone depletion	0.0000356	2.33E-06	2.33E-06	0	100%	0%	7%	0%
[C29]	terrestrial ecotoxicity	0.797	0.587	0.0344	0.5526	6%	94%	4%	69%
[C38]	freshwater aquatic ecotoxicity	1100	1090	2.98	1087.02	0%	100%	0%	99%
[C50]	human toxicity	441	394	7.03	386.97	2%	98%	2%	88%

Appendix F: Sensitivity analysis

Sensitivity of untreated emissions from landfills in Peru

Evaluating 750kg going to landfill without LFG collection and with 47% LFG collection

		SC1 (75% LF 25% open dump)	Total impact of sanitary landfill (0% LFG collected)	Total impact of sanitary landfill (47% LFG collected)	Unit
[C3]	eutrophication	0.292	0.0841	0.0841	kg PO4-Eq
[C5]	resource depletion	1.57	0.102	0.102	kg antimony-Eq
[C14]	acidification	0.964	0.0558	0.0558	kg SO2-Eq
[C17]	photochemical oxidation	0.0664	0.0227	0.013	kg ethylene-Eq
[C22]	climate change	365	103	67.3	kg CO2-Eq
[C46]	stratospheric ozone depletion	3.56E-05	2.33E-06	2.33E-06	kg CFC-11-Eq
[C29]	terrestrial ecotoxicity	0.797	0.587	0.587	kg 1,4-DCB-Eq
[C38]	freshwater aquatic ecotoxicity	1100	1090	1090	kg 1,4-DCB-Eq
[C50]	human toxicity	441	394	394	kg 1,4-DCB-Eq

Sensitivity of untreated emissions from open dumps in Peru

Evaluating only 250kg going to open dump

Label	Name	[A4] Output of [G4092] SC1 disposal of MPW into open dump - leachate	[A5] Output of [G4093] SC1 disposal of MPW into an open dump - LFG	Sum [A4] leachate + [A5] LFG	SC1 (LF & open dump)	Unit
[C3]	eutrophication	5.87E-05	-	0.00006	0.292	kg PO4-Eq
[C5]	resource depletion	-	-	0	1.57	kg antimony-Eq
[C14]	acidification	-	0.000551	0.0006	0.964	kg SO2-Eq
[C17]	photochemical oxidation	-	0.00691	0.007	0.0664	kg ethylene-Eq
[C22]	climate change	-	31.2	31.2	365	kg CO2-Eq
[C46]	stratospheric ozone depletion	-	-	0	3.56E-05	kg CFC-11-Eq
[C29]	terrestrial ecotoxicity	0.000126	0.00159	0.002	0.797	kg 1,4-DCB-Eq
[C38]	freshwater aquatic ecotoxicity	0.908	0.000187	0.91	1100	kg 1,4-DCB-Eq
[C50]	human toxicity	0.639	0.0767	0.72	441	kg 1,4-DCB-Eq