LaserJet Cartridge Environmental Comparison:
A Life Cycle Study of the HP 96A Print Cartridge vs. its Remanufactured Counterpart in North America

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Executive Summary

Objective

The primary objective of this study was to assess and compare the life cycle environmental impacts of Hewlett-Packard (HP) LaserJet toner print cartridges and leading remanufactured toner print cartridges available to customers. The results here provide for HP and other interested parties a thorough and unique environmental comparison of these cartridges across the entire product life cycle: from production to distribution to use to end of life.

HP has examined the environmental impacts and performance of toner cartridges through previous, independent research. In 1998, HP commissioned an independent evaluation of the life cycle environmental impacts of its LaserJet cartridges. One of this study's key findings was that paper production and use had the most significant contribution to the product's total environmental footprint. A 2003 study, conducted for HP by the testing firm QualityLogic, Inc., analyzed the reliability and print quality consistency of HP LaserJet cartridges in comparison to a number of key worldwide remanufacturers. QualityLogic found that HP cartridges produced usable printed pages more consistently and reliably than the tested remanufactured cartridges.

Often, environmental comparisons of originally manufactured and remanufactured cartridges focus on material sourcing and production, rather than the entire life cycle. However, the HP research noted above highlights the relative importance of printing performance as well as the different sources of the environmental impacts of laser printing. The extensive quantitative assessment of printing performance conducted by QualityLogic enabled an environmental comparison that considered the differences in product performance at the critical use stage of the cartridge life cycle.

The findings presented here build on this previous research using an internationally standardized method for evaluating products from production to end of life, called Life Cycle Assessment (LCA). A secondary goal of this study was to examine the present, conventional application of the Reduce-Reuse-Recycle "waste hierarchy" with regards to print cartridges to see if it adequately captures environmental impacts when the entire life cycle is examined.

The focus of this study – North America – was selected as the location of cartridge use, because of its large market size. Four different country scenarios – North America, United Kingdom, Germany and Asia – were applied to the LCA model to account for variations and provide a more applicable result across differing geographies. Each scenario is analyzed in a different version of this report. While effects of materials treatment and transportation distances have some impact on resulting data and scores, the overall findings of the study do not change across the studied geographies.

Project Approach

The Life Cycle Assessment (LCA) employs a holistic 'systems assessment' approach that is useful in identifying the environmental trade-offs inherent in any product value chain. This study adheres to the International Organization for Standardization's (ISO's) 14040 series of standards for LCA. The study was thoroughly reviewed by an external peer review panel with representatives from academia (Harvard University), the non-profit sector (Institute for Environmental Research and Education) and industry (AT&T).

Cartridges Examined

The scope of this project includes the full life cycle of four toner print cartridges: an HP LaserJet cartridge, which is manufactured, used once, and recycled in HP's current return and recycling program, and scenario representations of three types of compatible remanufactured cartridges. The life cycle stages for each scenario were based on well-known industry practices.

The HP cartridge (designated in this study as "HP 96A") was defined as the following:

- The HP C4096A is a LaserJet cartridge produced for use in the HP LaserJet 2100 and 2200 series printers, which, when originally sold, were targeted for the home and small office consumer. The LaserJet 2100/2200 series remains one of the most popular HP printing series, and the cartridge continues to sell in high volumes.

For the purposes of this study, a remanufactured cartridge (designated in this study as "R 96A") is one in which the plastic body, as well as varying numbers of other components, have been taken from a previously used cartridge. The cartridge must always be refilled with toner. Select components are typically replaced. Because of the variety of remanufacturing processes, this study considers three different representative remanufactured cartridge scenarios:

- Baseline – A remanufactured cartridge representing common remanufacturing practices.
- International Operation – Cartridges produced by a remanufacturing operation that is considered technically sophisticated and services multiple international markets. The cartridges in this scenario are modeled as having relatively high quality and reliability.
- "Drill and Fill" Operation – Cartridges of highly variable quality and reliability produced by a remanufacturing operation that uses the least intensive form of processing.

Data Utilized

As noted above, data from previous studies were utilized in the development of this LCA. Data from the QualityLogic study were used to define characteristics of the use stage for all four modeled cartridges: the HP and the three remanufactured scenarios. Specifically, measurements of "print quality consistency" (defined as the number of unusable pages produced during printing) and "page yield" in the LCA were derived from actual measurements by QualityLogic, which had examined cartridges purchased through typical distribution channels.

Print cartridge performance was also compared based on the printing on one side of monochrome pages. For the LCA, printing of 100 usable monochrome pages was defined as the "functional unit." It is important to note that the functional unit was based on the common measure of desired function, or service, of print cartridges, producing printed pages (for the purposes of this and the QualityLogic study, a "usable" printed page is defined as one that is sufficiently devoid of imperfections such that it can be used for business communications).

To define the key end-of-life management stage of the cartridges, the LCA posits an environmentally conscious consumer choosing between two disposal alternatives: returning the cartridge to HP's established return and recycling program through widely available and free-of-charge return mailing; and providing the cartridge to a remanufacturer through one of many widely available collection sites. For the remanufactured cartridges, the LCA evaluated various end-of-life management strategies, including varying degrees of recycling, energy recovery and landfill disposal.

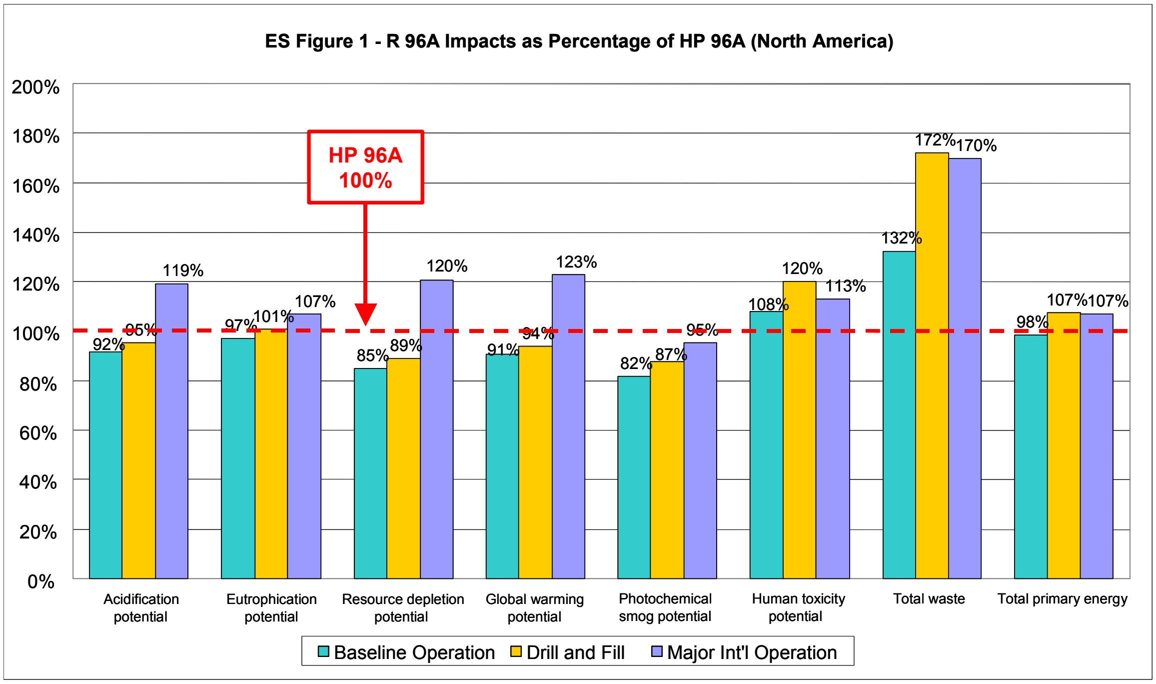
Results

The LCA measured life cycle impacts in eight categories: global warming potential; total energy; total waste; acidification, eutrophication, photochemical smog, and human toxicity potentials; and the depletion of natural resources.

Overall, these environmental impact comparisons, presented in ES (Executive Summary) Figure 1, do not decidedly favor the HP cartridge or any remanufactured cartridges. The results of certain life cycle impact assessment categories for remanufactured cartridges were less than those associated with the HP cartridge, and greater than the HP cartridge in other instances. All but three of the results differ by less than 20 percent; more than half differ by less than 10 percent. Therefore, no definitive statement can be made about the environmental preferability of one product type over the other – HP or remanufactured.

There was only one instance where a clear difference in environmental impact was observed. Significantly higher estimates of total waste were found for the "international" and "drill and fill" remanufactured cartridge scenarios than the other two product scenarios.

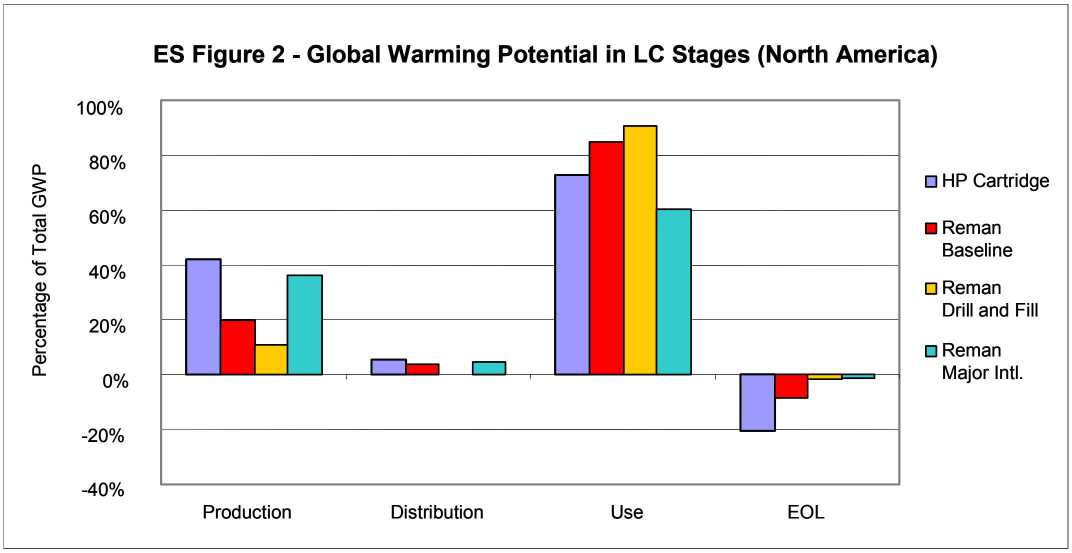
ES Figure 1: Life Cycle Impact Assessment Results as a Percentage of HP 96A



The charts that follow (ES Figure 2 and ES Figure 3) show the life cycle stage contributions to overall life cycle impacts for two of these categories: global warming potential (GWP) and total waste. These charts represent the relative share of impact across the four major life cycle stages: production, distribution, use, and end of life.

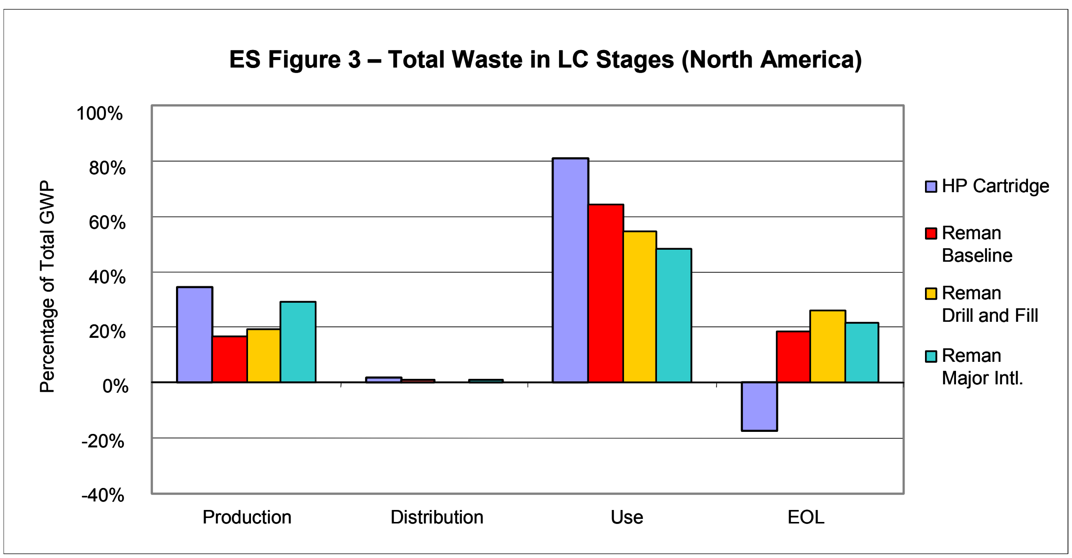
In comparing GWP results, the use stage accounts for a significant majority of the total life cycle impacts for all four cartridges. The HP cartridge's reliability and print quality consistency at the use stage offsets other life cycle stage impacts when compared to the remanufactured alternatives. Negative results at the end-of-life stage indicate the net benefits gained from recovery of materials or energy for beneficial use. Percent totals may appear to exceed 100 where cartridge recycling or energy recovery programs offset portions of total impact.

ES Figure 2: Life Cycle Stage Contribution Analysis – Global Warming Potential (Impact from generating 100 usable pages; data specific to North America LCA model)



In comparing total waste results, the volume of waste generated during the use stage accounts for 60-75 percent of the total waste for all four cartridges. The end-of-life management for the HP cartridge (through recycling programs and recovery of materials or energy for beneficial use) offsets the measurement of waste at other stages and affects the graph accordingly. Negative results at the end-of-life stage indicate the net benefits gained from recovery of materials or energy for beneficial use. Percent totals may appear to exceed 100 where cartridge recycling or energy recovery programs offset portions of total impact.

ES Figure 3: Life Cycle Stage Contribution Analysis – Total Waste (Impact from generating 100 usable pages; data specific to North America LCA model)



Conclusions

The results from this study challenge a common school of thought that remanufactured toner cartridges are "better" for the environment because they reuse materials in the development of a new cartridge. The study reveals that although material sourcing impacts are significant, critical drivers of environmental impacts over the life cycle are print quality, cartridge reliability and end-of-life management.

- Cartridge Reliability – Lower reliability that results in premature cartridge failures reduces the average page yield of a cartridge. Lower page yields result in an increase in environmental impacts per printed page because production, transport and end-of-life disposition impacts are associated with a smaller number of printed pages. Cartridge reliability, therefore, has potential for a considerable decrease in environmental impacts required to produce usable pages.

- Print Quality Consistency – This and previous studies have demonstrated that the greatest proportion of environmental impacts occur during the use stage through consumption of paper. Lower quality printing that results in unusable pages can increase paper consumption due to reprints, significantly increasing environmental impacts. Conversely, a cartridge that produces high quality output will minimize wasted pages.

- End-of-life Management – The benefits of a recycling program (recovery of materials and energy from end-of-life cartridges) offset the impacts at other life cycle stages.

Thus, a cartridge that reliably prints high quality pages, and in particular one that is recycled at end of life, most likely has lower overall environmental impacts than a cartridge that doesn't share these attributes. Indeed, the parity in environmental impacts amongst the originally manufactured and remanufactured cartridges has pointed to the fact that no definitive statement can be made about the environmental preferability of one product type over the other. This lack of differentiation is itself a significant finding, and calls into question the commonly promoted belief that remanufactured cartridges create far less environmental impact than originally manufactured cartridges, even when the original cartridges are recycled.

Applying the Waste Hierarchy

A key lesson to be taken from this study is that systems should be compared on a functional basis, not based only on sourcing and production. With the present application of the waste hierarchy to print cartridges (which emphasizes only one stage of the life cycle), remanufactured cartridges may appear to be environmentally preferable to HP and other originally manufactured cartridges, because reuse is conventionally placed at a higher importance than recycling. However, this narrow perspective fails to account for the production impacts of remanufacturing and further ignores the additional waste and environmental impacts, which could be generated at other stages of the product life cycle. These may include resources that are wasted because of inefficient printing.

This highlights the need to reconsider conventional thinking about cartridge environmental preference. Environmentally based decision-making regarding cartridges, whether original or remanufactured, should consider the cartridge's entire life cycle, and most importantly, take into account the service it provides: reliable performance and the printing of usable pages.

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Definitions

Cartridge Core

Remanufacturing industry terminology for a used cartridge body, used as input in the remanufacturing of cartridges.

Cartridge Selectability Number

A two digit cartridge designation, typically a shortened form of the HP Part Number, designed to help customers identify the correct cartridge for their printer.

First-Cycle Core

An OEM cartridge that has never been remanufactured. Also known as a "virgin core."

Functional Unit

Quantified performance of a product system for use as a reference unit in a life cycle assessment study (Reference 1).

OEM Cartridge

A cartridge produced by the printer original equipment manufacturer ("OEM"). Also known as an "original cartridge".

Page Coverage

The amount of a given page where toner is applied.

Page Yield

The average number of pages (usable and unusable) printed from a given cartridge type. In the case of this study, the relevant page yield is defined by the observations of QualityLogic. QualityLogic's observed page yields vary from HP specifications because of greater page coverage in their test pages.

Print Quality Consistency

The number of unusable pages produced during printing.

Recycling

Processing entire print cartridges or their components for beneficial use of recovered materials.

Remanufactured Cartridge

For the purposes of this study, a remanufactured toner cartridge is one in which the plastic body, as well as varying numbers of other components, have been taken from a previously used cartridge, refurbished to varying degrees depending on the remanufacturer, and replenished with toner.

Unusable page

Printed page with Print Quality Levels 1, 2, or 3 as defined by QualityLogic, i.e., page is "sufficiently flawed such that it would not be circulated to others as a business document and would only be acceptable as a draft page,".(Reference 5)

Usable page

Printed page with Print Quality Level 4, i.e., "may have a minor flaw such as a speck or uneven graphic rendering but the average user would still use it in a typical business document" or Level 5, i.e., "has no apparent artifacts with the identifying rule of thumb being that a user would put this page in his or her resume", as defined by QualityLogic. (Reference 5)

Waste to Energy

Waste to Energy (WTE) is the management of waste through controlled incineration with recovery of usable energy or electricity.

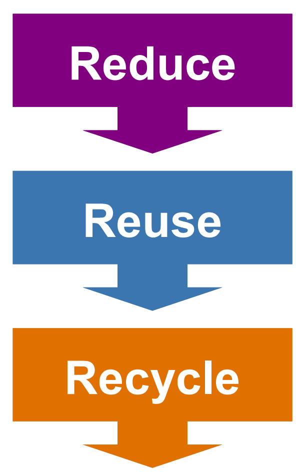
Section 1

Introduction, Goal and Intended Uses

In 1998, Hewlett-Packard (HP) commissioned research to evaluate the life cycle environmental impacts of one of its LaserJet cartridges. One of the key findings from this Life Cycle Assessment was that the use of the cartridge (i.e., printing-related aspects and paper use in particular) had the most significant contribution to the product's total environmental footprint. In an unrelated study conducted for HP in 2003, QualityLogic, Inc. (QualityLogic), a testing firm, analyzed the reliability of HP LaserJet cartridges compared to key worldwide brands of remanufactured toner cartridges. After testing thousands of pages from each cartridge using sample page templates and simulating real world printing conditions, the study found that HP cartridges more reliably produce usable printed pages.

These findings highlight the relative importance of the effects of print quality as well as the wide range of sources for environmental impacts of laser printing. The extensive quantitative assessment of printing performance conducted by QualityLogic enabled an environmental comparison that considered the differences in product performance at the critical use stage of the cartridge life cycle. With this in mind, HP commissioned this Life Cycle Assessment (LCA) with the goal of combining the data in a model that assesses the life cycle environmental impacts of two options available to a consumer of monochrome toner cartridges: an original HP LaserJet cartridge, recycled through HP's current return and recycling program, and comparable remanufactured cartridges with various end-of-life management scenarios. Various scenarios of remanufacturing practices are also evaluated, each of which is designed to be as realistic and representative as possible to true remanufacturing cartridge market situations. First Environment Inc. was commissioned to perform this LCA.

The Waste Hierarchy



The 'waste hierarchy' is a protocol for waste minimization and management that has been adopted by local, state and federal governments around the world. Broadly, the hierarchy emphasizes that a 'reduce-reuse-recycle' philosophy be used when any organization looks to manage the generation of solid waste.

The first step in the hierarchy, Reduce, emphasizes minimizing the generation of waste to begin with through more efficient management of materials. The second step, Reuse, involves the multiple uses of a product by repairing or reconditioning them, donating them, or selling them for either its original or an alternative purpose. The third step, Recycle, emphasizes the recovery and processing of waste material that would otherwise be landfilled or incinerated.

For printer consumables, this hierarchy could be represented as printing less often or more reliably (Reduce), recovery and refilling of the waste cartridge (Reuse), and then recovery of the waste cartridge at the end of its useful life (Recycle). Often, for printer consumables, the reuse of cartridges through the purchase of remanufactured cartridges is presented as the 'best' environmental option compared to purchasing an original equipment manufactured (OEM) cartridge with an effective recycling program.

This study will focus on whether or not this dynamic is an accurate representation of the environmentally preferable situation.

Life Cycle Assessment

Life Cycle Assessment (LCA) is a methodological approach that uses a quantitative and scientific approach to evaluating the 'true' environmental impacts of products and their systems. LCA uses a holistic 'systems assessment' approach that is useful in identifying the environmental trade-offs (e.g., high solid waste but low energy use) that are inherent in any product value chain. In order for LCA to be an effective and well-accepted approach, standard LCA guidelines were developed, with the most widely accepted being the International Organization of Standardization's (ISO's) 14040 series of standards.

This study adheres to the LCA guidelines provided by these standards:

- ISO 14040:1997(E), Life cycle assessment. Principles and framework.
- ISO 14041:1998(E), Life cycle assessment. Goal and scope definition and inventory analysis.
- ISO 14042:2000(E), Life cycle assessment. Life cycle impact assessment.
- ISO 14043:2000(E), Life cycle assessment. Life cycle interpretation.

This new study is a full LCA, which meets the essential requirements formalized by the ISO series of standards. Specifically:

- The project aimed to account for the environmental inflows and outflows associated with the cradle-to-grave life cycle of products;
- The goal and scope of the project were precisely defined;
- Assumptions were transparently stated, and the system boundaries, functional unit, and other pertinent aspects of the study were defined and described;
- Pertinent data were collected, and their quality was rigorously assessed; and
- Reporting requirements were included.

To ensure compliance with ISO requirements, HP commissioned an independent, external critical review pursuant to the ISO 14040 guidelines. The study was thoroughly reviewed by an external peer review panel with representatives from academia (Harvard University), the non-profit sector (Institute for Environmental Research and Education), and industry (AT&T).

Uses for the Study and Limitations

While the goal of this study is to evaluate the comparative environmental profiles of HP and remanufactured cartridges, its use is not limited to environmental reporting. The study has been designed to transparently present the tradeoffs between two different products so that it can be used to:

- Inform policy and purchasing decisions relating to the environmental impact of toner cartridges;
- Assess the applicability of the waste hierarchy to printer cartridges;
- Identify opportunities for product and/or process improvements;
- Provide a source of environmental information to interested parties; and
- Provide a benchmark assessment from which HP and other interested parties can measure future environmental progress relative to toner cartridge operations.

This study looks at cartridge use in North America. The study will be adapted for other regions, including adjusting transportation distances, energy production practices and solid waste disposition. Locations for additional modeling are Germany, the United Kingdom and Asia**.**

As with any life cycle study, there are some limitations to how it should be used. LCA results should not be considered to be the only source of environmental information relating to the environmental performance of a product or process. Also, as is common with an LCA, there are limitations to data quality, especially for the production of upstream sourcing materials, where temporal, geographical, and technological information vary widely. So when hundreds of data sets are compounded into a life cycle system, the result is a snapshot of a system, which has to account for some factor of error.

Section 2

Scope Definition and Methodology

This section presents the project scope, introduces the cartridges studied, and provides an outline of the system boundaries and general methodology. Detailed information on the modeling methodology and the life cycle stages for the cartridges are provided in the Modeling and Assumptions section (Page 15).

Project Scope

The scope of this project includes the full life cycle of both the HP LaserJet cartridge and three typical scenarios of compatible remanufactured cartridges, and accounts for raw material extraction, manufacturing, transportation, use, and end-of-life disposition.

Description: HP LaserJet Cartridge

The HP C4096A (designated as HP 96A in this study) is a LaserJet cartridge produced for use in the LaserJet 2100 and 2200 series printers, which when originally sold, were targeted at the home and small office consumer. The LaserJet 2100 and 2200 series remains one of the most popular HP printing series, and the cartridge continues to sell in high volumes. HP outsources production of the HP 96A, which takes place at one of two assembly sites in Japan.

The HP 96A was chosen as the study subject based on the following three criteria:

- Inclusion in the QualityLogic reliability study. The HP 96A was one of the cartridges rigorously tested in the 2200 printer by QualityLogic.
- Similarity to study subjects in previous LCAs. The HP 96A is similar to the 92298A cartridge, the subject of the 1998 LaserJet LCA (see Appendix 1). It was expected that the importance of paper in the cartridge life cycle would be similar for both cartridges.
- Large sales volume. The HP 96A has many remanufactured counterparts, a large sales volume, and a broad market usage, from consumer to office.

The data for the HP cartridge in this study were also based on QualityLogic study data. These data are actual measurements of cartridge reliability and print quality consistency, using cartridges purchased through typical distribution channels and used under representative conditions.

HP has an established LaserJet cartridge return and recycling program available in over 30 countries. Within this program, HP customers may send empty cartridges free of charge by mail to be recycled at an HP facility. The objective of this study is to assess the alternatives available to the consumer. We have assumed that the consumers utilizing this study to inform their purchasing decisions will avail themselves of environmentally sensitive disposal options by either returning their empty cartridge to HP or providing it to a remanufacturer.

Description: Remanufactured Cartridges

For the purposes of this study, a remanufactured toner cartridge (designated as R 96A in this study) is one in which the plastic body, and various other non-image producing components inside the cartridge, have been taken from a previously used and empty cartridge. The cartridge must always be refilled with toner and selected components are typically replaced. The components that are replaced vary among remanufacturing brands.

HP market research indicates that it is a common remanufacturer practice to replace at least the Organic Photoconducting ("OPC") drum and wiper blade. Other major components, such as the developer roller, may also be replaced. Some remanufacturers reuse every component they can, while others have a policy of replacing most. According to *Recharger* magazine, a leading publication of the remanufacturing industry, "To reduce failure rates, many remanufacturers have … opted to replace all components at each cycle."[1,2] Each remanufacturer has an individual production strategy to minimize cost while producing an acceptable level of quality.[3] Other environmentally significant aspects of the remanufactured cartridge industry include distribution and waste management logistics.

Defining the remanufactured cartridge for this study was not a simple exercise: no remanufacturer replaces all the imaging components all the time, quality varies and, in general, remanufacturing practices along the supply chain are broad. Thus, to meet the goal of comparing the HP OEM cartridge to a remanufactured cartridge, we defined the baseline remanufactured cartridge as representing common remanufacturing practices. Quantities of usable pages per cartridge, and cartridge reliability, as represented by average page yield, were based on QualityLogic study results. Two additional cartridge remanufacturing scenarios were also developed to examine variations in practices and different levels of quality. It should be emphasized, however, that none of these models was intended to reflect a specific brand of remanufactured cartridge. Instead they should be considered as cartridges remanufactured using well-known industry practices and representative of those that could be found in the marketplace.

The print quality and usable page yield for the baseline and scenario cases were based on QualityLogic test results. The QualityLogic study looked at several leading remanufactured brands. Therefore, it can be assumed that the tested cartridges represent average or better performance, and the reliability and print quality consistency data used for this study yield a conservative comparison.

While end-of-life management practices appear to vary within the remanufacturing industry, there is no large scale established recycling program. Evidence also suggests that remanufactured cartridges have a higher chance than the HP cartridge of ending up in the municipal solid waste stream (see detail in Section 3). The remanufactured cartridge is noted in this study as R 96A.

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[1] Geurts, David. "Quality Control in a Toner Cartridge Production Line." *Recharger.* April 1, 2003. pp 68, 70, 74, 78.

[2] This statement is probably refers to all image producing components.

[3] Appendix 4 provides a more detailed overview of the remanufacturing process.

Function and Functional Unit of the Cartridges

To conduct an accurate LCA model under ISO guidelines, the function of the system should be defined so that the inventory results of the model can be understood on the basis of that function. Once this function is defined, a functional unit is chosen so that the systems can be compared on the same quantitative basis. For example, the comparison of the life cycles of an aluminum can and a plastic bottle is made on the function that each product serves, i.e., packaging a quantity of a beverage, not on the basis of their materials, i.e., one pound or kilogram of aluminum versus one pound or kilogram of plastic.

Likewise, the cartridge comparison is being made in terms of the function of printing pages, so that it is fairly based on the service that the cartridge provides, not on a physical cartridge to-cartridge comparison. Thus, the function of the system is defined here as printing to obtain usable pages, i.e., pages sufficiently devoid of imperfections such that they can be used for business communication. The functional unit is defined as the printing of 100 usable monochrome single-sided pages. The paper type selected is addressed later in the report. As modeled, printed pages conform to the protocol established by QualityLogic in their study.

System Boundaries

Inclusion of Data in the System Boundaries

The cartridge life cycle stages included in the system boundaries are:

- Production: production of the materials in each cartridge and cartridge assembly (includes the sourcing of materials – be it transportation of used cartridge to remanufacturing facility and/or the extraction/refinement of needed metals and plastics to make new components in cartridge manufacture).
- Distribution: delivery of the finished product to the end user.
- Use: end user operation to produce the functional unit. This includes printing requirements, i.e., paper and cartridge-related resources needed to print 100 usable pages.
- End of Life: fate of the cartridge after it is depleted of toner.

Figure 1 represents the system boundaries for the HP and remanufactured cartridge systems, as well as how they relate to the functional unit. The portions of the system boundaries that are not included or partially included will be discussed in the Modeling and Assumptions section.

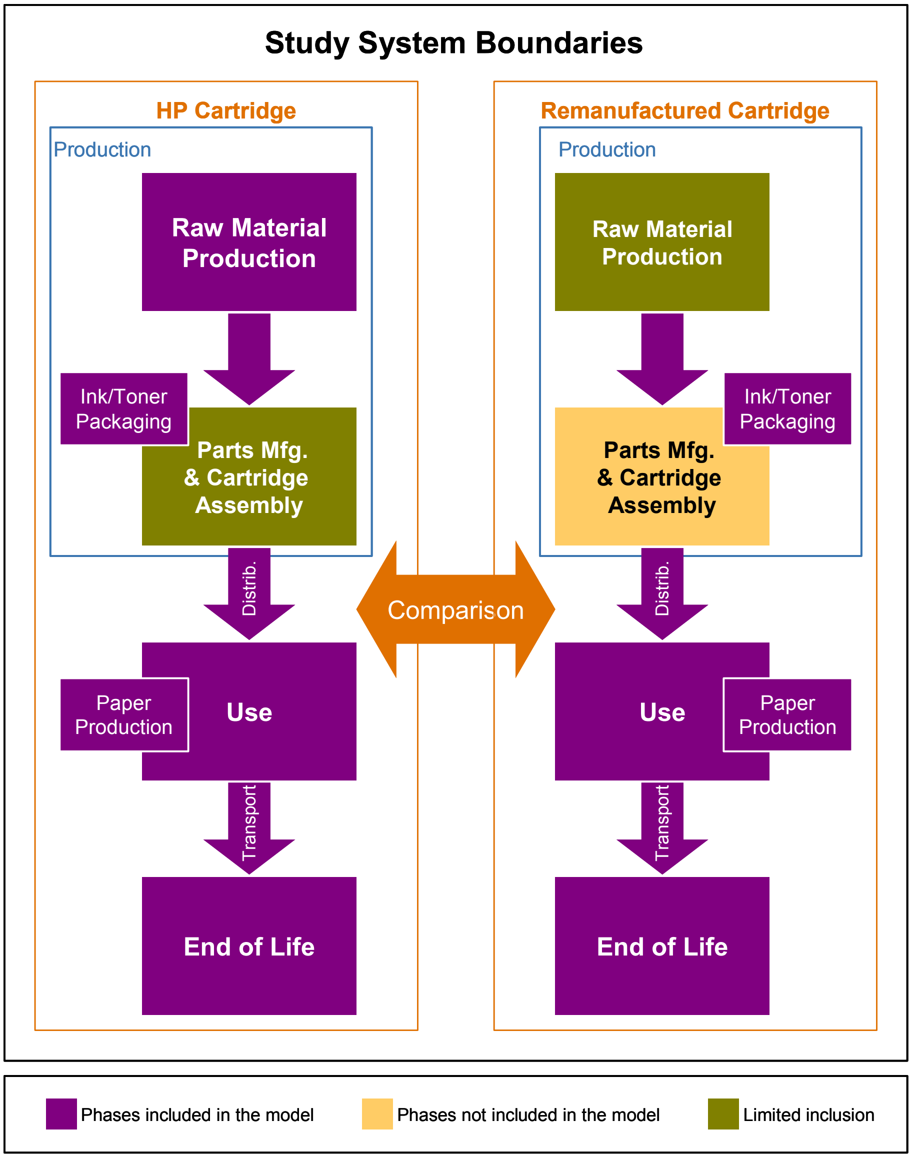
Modeling of Single-Cycle Cartridges

Note that this study compared a single-use HP cartridge and a "single-cycle" remanufactured cartridge. Industry data strongly suggest that of the used cartridges (known in the industry as "cores") that are remanufactured, most are remanufactured only a single time, or a single "cycle." According to a prominent remanufacturer trade publication, "[In] 2000, at least 70 percent of first remanufacturing cycle cores were abandoned."[4] In a related article, the same

[4] Golden, Chad. "Worth Their Weight in Gold, Mining for Cartridge Core Profitability." *Imaging Spectrum*. August 2002. pp 25-30.

author examines the prevalence of single cycle remanufacturing, finding that "virgin empties constitute almost 83 percent of the total aftermarket production of AIO [All-in-One device toner] cartridges."[5] Some remanufacturers claim a "virgin-only" strategy – or favoring cartridges that have been not been reused previously – as a quality feature.[6]

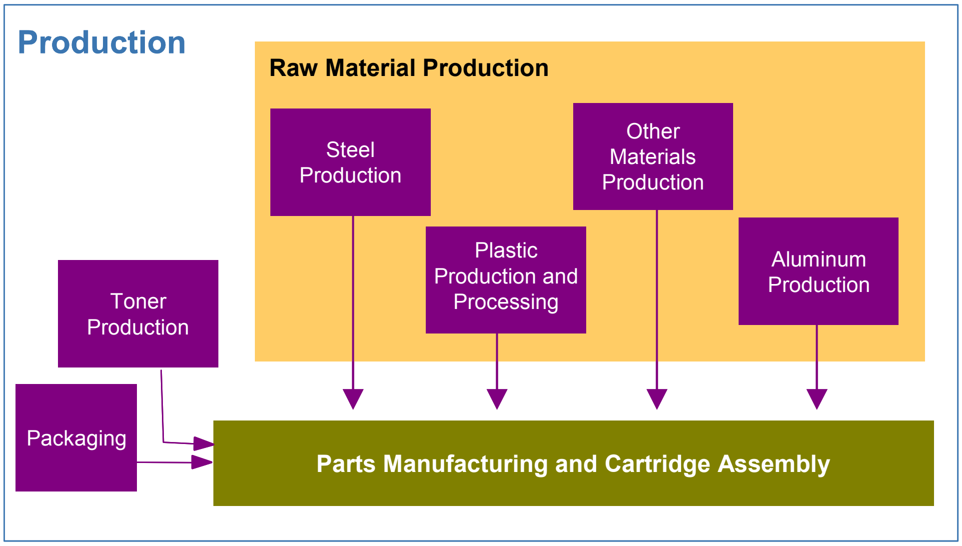
Figure 1: Overall Study System Boundaries



[5] Ibid. "Worth Their Weight in Gold-Part 2: Solutions for Cartridge Core Profitability." *Imaging Spectrum*. September 2002. pp 26-31. The author also notes that "only 17.2 percent of current production is based on the [multiple] reuse of a core, and second-cycle usage of a core is estimated at 80 percent of all multi-cycle core usage."

[6] See for example the Peach, Inc 2004 Product Catalogue, p. 9, "The Peach Rebuilt Toner modules utilize cartridges that have never been reconditioned before." (available at http://www.peach.info/)

Figure 2: Production System Boundaries



Multiple-cycle remanufacturing as a scenario was considered at the onset of the study. OEM cartridge environmental impacts can be easily demonstrated by the linear increase in production, use, etc., given the same quality OEM cartridge produced each time. However, modeling environmental impacts of successive cycles of cartridge remanufacturing presents some unique challenges. As a cartridge goes through additional cycles, more assumptions and modeling are necessary. For example, additional remanufacturing cycles can entail different transport, a higher percentage of cartridges that cannot be processed, and greater amounts of component replacement. Most importantly, data on the effect of multiple-cycle remanufacturing on cartridge reliability and print quality consistency were not available, although virgin-only remanufacturing strategies suggest reliability and quality will decline. Therefore, since it is well documented that the majority of remanufactured cartridges on the market are single-cycle, and because the environmental impacts of cartridge reliability and its print quality consistency are a critical study dimensions, it was determined that modeling single-cycle remanufacture would yield the most meaningful results. Thus, only single-cycle remanufacturing is modeled in this study.

Exclusion of Data from the System Boundaries

Two elements of the cartridge life cycle have been excluded from the system boundaries for this project[7]: capital equipment and human-related activities. This is standard practice for most LCAs and the reasons are described briefly below.

Capital Equipment

Capital equipment, such as the production and transportation of concrete and steel for facility and transportation infrastructure, has been excluded since its contribution to the overall life cycle is expected to be small. [8]

[7] Note: this is consistent with the past LCA studies referenced in this study and is common LCA practice.

[8] For more information on this topic, see DeLuchi, M. A., 1993. Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity and Boustead, I, May 1997.

Human Involvement

People involved in the cartridge production life cycle do have a burden on the environment by driving to and from work, generating waste, etc., which is within the system boundaries for this LCA. However, human activities are generally excluded from an LCA since it can be argued that these same people would still contribute to environmental factors whether or not the cartridge existed.

Data Coverage and Data Quality

This study has adhered to the ISO standards on data quality to help ensure consistency, reliability, and straightforward evaluation of the results. The data quality section (see page 43) evaluates the following data aspects for this study, pursuant to ISO 14041 Section 5.3.6:

- Time/temporal coverage – describes the age of data and the minimum length of time (e.g., one year) over which data should be collected;
- Geographical coverage – describes the geographical area from which data for unit processes are collected to satisfy the goal of the study; and
- Technological coverage (or the technology mix) – This may include weighted average of the actual process mix, best available technology, or worst operating unit.

ISO 14041 Section 5.3.6 highlights additional data quality requirements, depending on the number of data sets and on the goal and scope definition of a given study. Also presented in the data quality section, these include:

- Consistency – the qualitative assessment of how uniformly the study methodology is applied to the various components of the analysis;
- Reproducibility – the qualitative assessment of the extent to which information about the methodology and data values allows an independent practitioner to reproduce the results reported in the study;
- Representativeness – the qualitative assessment of degree to which the data set reflects the true population of interest (i.e., geographical coverage, time period and technology coverage);
- Precision -- the measure of the variability of the data values for each data category expressed;
- Completeness – the percentage of locations reporting primary data from the potential number in existence for each data category in a unit process.

Impact Assessment Data Categories

The life cycle impact assessment is the part of the LCA "aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system."[9] The life cycle impact assessment categories chosen for the study are found in Table 1.

Table 1: Life Cycle Impact Assessment Categories

Impact Assessment Category	Reported Unit
Global warming potential	Carbon dioxide (CO_2) gram equivalents
Acidification potential	Hydrogen ion (H+) gram equivalents
Eutrophication potential	Phosphate (PO_4) gram equivalents
Depletion of non-renewable resources	Mega joules (MJ) of energy surplus
Photochemical smog potential	Ethylene gram equivalents
Human toxicity potential	Disability-Adjusted Life Years (DALYs)
Total energy	Mega joules (MJ)
Total waste	Kilograms

This list generates a broad cross section of impacts within different environmental media (i.e., air emissions, water effluents, waste, etc.) and endpoints (vegetation, human health, etc.). Appendix 2 provides the characterization factors for each of the impact categories, with the exception of total waste and total energy, which are inventory results in themselves and do not have any weighting factors.

Global Warming Potential

The "greenhouse effect" refers to the phenomenon by which atmospheric gases are able to retain energy radiating from the earth, creating a "blanket" around the earth resulting in an overall increase in temperature. The global warming potential (GWP) impact category characterizes the increase in global warming from greenhouse gas emissions generated by human-related activities. The GWP was calculated in this study for a 100-year time horizon.

[9] ISO 14040:1997(E), Section 5.3.

Table 2 below presents major air emissions classified in GWP, their characterization factors (for GWP, in gram equivalents of CO_2), and a sample calculation demonstrated to obtain the GWP result.

Source:

Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis,* Cambridge, UK: Cambridge University Press, 2001.

Table 2: Sample Impact Assessment Calculation Using GWP

Major substances classified into GWP	Characterization factor (CO_2 eq.)	Emission quantity from sample life cycle inventory results (g)	GWP (g CO_2 eq.)
Carbon dioxide	1	4,000	4,000
Methane	23	75	1,725
Nitrous Oxide	296	3	888
		Total:	**6,613**

Acidification Potential

Acidification Potential is the impact by which acidifying gases may dissolve in water (i.e., acid rain) or fix on solid particles and degrade, or affect the health of, vegetation, soil, building materials, animals, and humans. Acidification is measured in terms of gram equivalents of hydrogen ions.

Source:

Centre of Environmental Science (CML), *Environmental Life Cycle Assessment of Products*: *Guide and Backgrounds*, Leiden University, The Netherlands, October 1992.

Eutrophication Potential

Eutrophication Potential is the impact by which nutrient-rich compounds (both as water effluents and air emissions) are added to water bodies, resulting in a shift of species in an ecosystem and a potential reduction of ecosystem diversity. A common result of eutrophication is the rapid increase of algae, which depletes oxygen in the water and causes fish to die. Eutrophication potential is measured in phosphate (PO_4) gram equivalents.

Source:

Centre of Environmental Science (CML). *CML 2 Baseline 2000 Method*, Leiden University, The Netherlands, 2001.

Resource Depletion Potential

Resource depletion is assessed in terms of surplus energy, defined as the energy needed for future extraction of less accessible or lower grade resources. The current amount of energy needed to extract current reserves will increase as these reserves become less attainable. This surplus energy is measured for both minerals and fossil fuel.

Source:

PRé Consultants, *Ecoindicator 99* (2000 update, update from *EcoIndicator 95*), Amersfoort, Netherlands. http://www.pre.nl/eco-indicator99/ei99-reports.htm.

Photochemical Smog Potential

Under certain climatic conditions, air emissions from industry and transportation can be trapped at ground level where they react with sunlight to produce photochemical smog. One of the components of smog is ozone, which is not emitted directly, but instead is produced through the interactions of hydrocarbons and nitrogen oxides. This indicator tracks flows related to such interactions and is expressed in grams of ethylene.

Source:

United Nations Economic Commission for Europe, *Protocol to the convention on long-range transboundary air pollution concerning the control of emissions of volatile organic compounds of the transboundary fluxes*, Geneva, 1991.

Human Toxicity Potential

For the human toxicity potential of emissions, this study used the human health calculation developed for Eco-Indicator 99, which covers three separate steps:

1. Fate analysis – from emission to concentration.
2. Effect analysis – from concentration to cancer cases per kg emission.
3. Damage analysis – from cancer cases per kg to Disability-Adjusted Life Years (DALYs) per kg emission.

Fate analysis for emissions to air, water, urban soil and industrial soil is carried out for 53 substances. The three exposure pathways – air (inhalation), drinking water (oral uptake) and food (oral uptake) – are considered. For exposure to metals through food, specific transfer coefficients have been used to calculate the exposure. For the effect analysis, a list of unit risk (UR) factors is used. The unit-risk concept, developed by the World Health Organization, is used to estimate the dose response relationship.

An example of the unit risk factor is: for inhalation, it is an estimate of the probability that an average individual will develop cancer when exposed to a pollution at an ambient concentration of one microgram per cubic meter for the individual's life (70 years) [UR in cases per g/m^3]

The final step, damage analysis, relies on the estimation of DALYs per incidence case. For this estimate, information on the seriousness of the illness, the duration, the death rate and age of the people affected are used. The total DALYs per kg emission to a specific compartment for a specific perspective are calculated by adding the different exposure pathways.

The human toxicity assessment results should be used with caution in light of some of the intrinsic limitations of life cycle impact assessments:

- Spatial and temporal resolution data that may be applicable to a localized or site-specific study is lost in an LCA. The normalization of emissions from processes in a system to the functional unit erases all temporal and geographical characteristics, which are needed to assess local environmental impacts.
- Threshold information is lost in an LCA.

Source:

PRé Consultants, *Ecoindicator 99* (2000 update, update from *EcoIndicator 95*), Amersfoort, Netherlands. http://www.pre.nl/eco-indicator99/ei99-reports.htm.

Total Energy

Total energy includes all energy inputs to processes in the system, taking into account embodied energy (i.e., in the plastic components in the cartridge) as well as fuel energy (process energy, transportation energy, etc.). Energy losses from electricity grid loss, boilers, and other inefficiencies are also taken into account in total energy.

Waste

Waste accounts for the various waste categories in the system whose fate is presumably an industrial landfill (hazardous and non-hazardous), municipal solid waste (MSW) landfill, or an incinerator. The categories include:

- Hazardous waste,
- Municipal and industrial waste,
- Nontoxic chemicals,
- Non-hazardous chemicals waste,
- Inert waste,
- Waste in Landfill,
- Flue gas desulfurization sludge,
- Unspecified slag and ash,
- Unspecified waste,
- Unspecified waste to incineration.

External Critical Review

An external critical review panel was chosen for this study in order to check the assumptions made in the study and the study's technical validity, as well as improve its credibility. The critical review process is intended to ensure that[10]:

- The methods used to carry out the LCA are consistent with the ISO 14040 series on LCA;
- The methods used to carry out the LCA are scientifically and technically valid;
- The data used appear to be appropriate and reasonable in relation to the goal of the study;
- The interpretations reflect the limitations identified and the goal of the study; and
- The study report is transparent and consistent.

The ISO 14040 guidelines state that if a critical review is to be performed externally, the review should be carried out by experts independent of the study. The review panel was selected for this study based on the individuals' familiarity with the requirements of the ISO standards for LCA and/or expertise in the information technology sector. The panel -- representatives from academia (Harvard University), the non-profit sector (Institute for Environmental Research and Education) and industry (AT&T) – thoroughly reviewed the study and verified that ISO standards were adhered.

[10] ISO 14040:1997(E), Section 7.1.

Section 3

Modeling and Assumptions

Baseline Cartridge Life Cycles

This section presents the modeling and assumptions made for the baseline HP and remanufactured 96A cartridges. HP's baseline life cycle model is based on actual industry knowledge. The baseline remanufactured cartridge and additional remanufactured cartridge scenario models were based on data in several LCA studies, remanufacturing trade publications, remanufacturer company literature, and market research.[11] The specific steps in the life cycle are modeled below.

Production

HP 96A Production

The HP 96A production stage model incorporated the production of over 99.5 percent (by mass) of the cartridge, as provided in HP's current Parts and Materials List (Reference 5)[12], plus the production of toner and final product packaging materials (see Table 3), not part of the Parts and Materials List. An average distance of 300 miles by truck was assumed to transport these materials to their place of manufacture into cartridge parts. Since the location of manufacture of many of these materials is unknown, 300 miles was chosen as a representative distance for road transport within Japan.

Table 3: HP 96A Packaging Materials

Component	Brief description; Materials	Weight
Paperboard	External packaging. Modeled as recycled cardboard.	330 g
Composite	Internal packaging. Consists of PET, LDPE, aluminum foil, and polyurethane adhesive.	50 g
End caps	Internal packaging. Made from 100 percent post consumer recycled material. Impacts of production not accounted for.	74 g

Source: HP Web site

There was insufficient data available to completely model processing into individual cartridge parts and the actual cartridge assembly process. Material processing for some of the raw materials was included. For example, injection molding data was added to the model for polystyrene production, which makes up approximately 40 percent by mass of the cartridge.

[11] See, for example, University of Kalmar, Life Cycle Assessment of Toner Cartridge HP C4127X, January 2002; Perfect Print Sweden AB, SmartToner EP-E, Pre-certified environmental product declaration (EPD) Reg.nr: S-EP-00009; and Centre for Design, *Life Cycle Assessment of the Printer Consumables Waste Stream Before and After the Introduction of the Cartridges for Planet Ark Program. An Australian Context*, May 2003.

[12] The Parts and Materials List is an inventory of the materials composed of the LaserJet cartridge. A description of the major internal components of the cartridge is found in Appendix 3.

But the remaining 60 percent by mass – for example, impacts associated with the forming of individual parts from metals – were not included. While the remaining 60 percent of process impacts are unknown, it is not unusual in LCA studies to find that process impacts are small compared to the material production impacts. And as will be described below, similar data gaps exist for the remanufactured cartridge. Thus, it can be assumed that the relative difference in processing impacts for assembly (OEM) and disassembly/assembly (remanufacturer) is small enough to make a meaningful comparison possible without process data. The inclusion of injection molding impacts helps avoid bias toward HP in this approach. Table 5 summarizes what is and is not included in the production stage of the HP 96A, and the limitation of the manufacturing data gap is also addressed in this report.

R 96A Production

In the baseline model, the R 96A, depleted of toner, is modeled as transported 500 miles from its user in the St. Louis, Missouri, chosen for its central location in the United States, to the remanufacturing plant. As noted previously, HP market research indicates that it is common remanufacturer practice to replace at least the OPC drum and wiper blade on the used cartridge. Thus, this baseline case models the OPC drum as being replaced, with the used drum discarded per the U.S. current municipal solid waste (MSW) management scenario, i.e., 86 percent to a landfill and 14 percent to an incineration plant that recovers energy (i.e., waste-to-energy (WTE) facility).[13] The wiper blade, a minor component (by weight), is not replaced. This more conservative assumption is examined in the sensitivity analysis that tested the model with all materials (except housing), and no materials, replaced. In addition, the baseline case models the toner as being refilled (quantity assumed to be the same as for the HP 96A)[14] and the cartridge packaged as per Table 3 in the HP section above. Appendix 4 provides a more detailed description of remanufacturing practices.

The production stage of the baseline remanufacturing model also accounts for the collected cartridges not suitable for remanufacturing. Published data was not available regarding the rejection ("sort and discard") rate of used cartridges prior to the remanufacturing step. However, in late-2002, CAP Ventures, Ltd., a market research firm that serves the digital imaging industry, conducted a qualitative telephone survey of European cartridge remanufacturers and brokers. Although the survey was not commissioned by HP, CAP Ventures later provided the results. Among the questions asked was, "What percentage of cartridges can be re-used for inkjet and toner?" Response from brokers and remanufacurers to the question varied between 75 percent and 96 percent for toner cartridges. The most frequent answer was 80 percent of toner cartridges can be re-used, equating to a 20 percent sort and discard rate.[15] At least one respondent indicated that discarded cartridges were sent to landfill.

CAP Ventures treated cartridge brokers and remanufacturers equally in the survey. In practice, brokers and remanufacturers are often successive points within the same supply chain. Thus a sort and discard rate for a broker alone would not represent the rate for the entire system. For example, a broker with a 20 percent sort and discard rate supplying used cartridges to a remanufacturer with a 20 percent sort and discard rate, would yield an overall sort and discard rate of 36 percent. A sort and discard rate of 20 percent overall, a conservative assumption,

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[13] The WTE model is described on page 22.

[14] Although toner quantity is assumed to be the same in this study, remanufacturers have been known to overfill their cartridges. Instead of an expected higher usable page output, this overfilling has actually been shown to decrease the quality of the printed pages.

[15] CAP Ventures, Ltd., Private communication to HP, 2003

was used in the baseline scenario. This sort and discard rate was examined in the sensitivity analysis. Disposition of discarded cartridges was modeled according to the U.S. MSW management scenario.

There was limited data on manufacturing and assembly, not counting the broadly varying remanufacturing practices over the thousands of remanufacturing organizations. While the disassembly/assembly process impacts may be small in the context of the whole life cycle, the impacts are unknown.

Distribution

The distribution stage refers to the delivery of the packaged cartridge from the final assembly to the end user. The HP 96A was transported by ocean ship, barge and truck from its place of manufacture in Japan to the end user in the United States. The remanufactured cartridge baseline was transported 1,500 miles by truck from the remanufacturing operation, assumed to be in the central United States (St. Louis, Missouri).

International transport of empty cartridges for remanufacturing is a well-known industry practice. Many cartridge remanufacturing companies collect cartridges in multiple countries, with associated transport to remanufacturing facilities. Major remanufacturers have production facilities in locations with lower labor costs, like Mexico, Thailand, China, and Eastern Europe. Cartridge remanufacturers and empties brokers internationally sell and buy empty cartridges using global trading portals such as www.empties.com. The baseline scenario considers collection, remanufacture and use within the same region. Shorter (local) and longer (intercontinental) transport distances are considered in the alternate remanufacturing scenarios, as well as the sensitivity analysis.

Cartridge Use

Use stage modeling accounted for the production of paper needed for printing as it related to the cartridge's page yield and number of usable pages, as well as for electricity use by the printer during printing. Each of these aspects is broken down below.

Page Yield

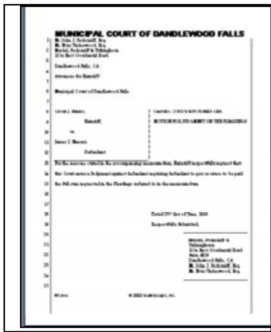
Page yield is defined in this study as the average number of pages printed per cartridge, without consideration of the print quality. The HP-specified page yield for the HP 96A is 5,000 pages, measured at five percent of page coverage,[16] which is typical for text documents. QualityLogic's test pages had a higher percentage of page coverage (as much as 22 percent, see also figure 3), which resulted in a lower page yield per cartridge: 2,960 pages for the HP 96A and a total average of 2,741 pages for the R 96A. QualityLogic's observed page yield for both types of cartridges was used for the baseline but the sensitivity of scaling the pages up to the maximum of 5,000 pages was examined in the sensitivity analysis.

It should be noted that the page yield presented by QualityLogic is an average yield, which affected by nonfunctioning cartridges, or cartridge failures. In other words, as cartridge failures for the sample of a given brand went up, the brand's average yield decreased. This is the only way that cartridge failures are accounted for in this study. There are some cartridge impacts

[16] See definitions table.

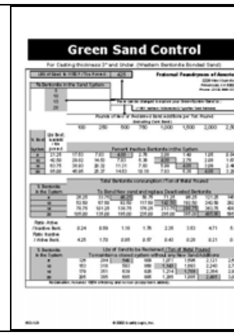
that are not accounted for with this approach, such as printer damage and rerunning partially completed print jobs. Therefore, this page yield approach is more conservative since the remanufactured cartridges had higher rates of failure compared to the HP OEM cartridges in the QualityLogic study. Appendix 5 provides more detail of QualityLogic's methodological approach.

Figure 3: QualityLogic Study Test Pages for LaserJet Cartridges

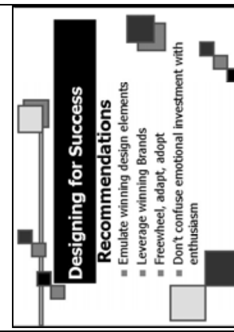


File: M1
Application: Microsoft Word XP
Description: Word Document
Coverage: 5 percent

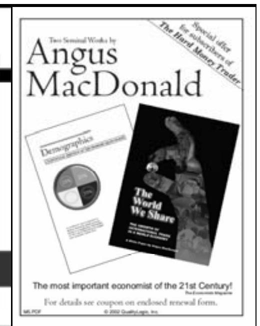
File: M2
Application: Microsoft Internet Explorer 6.0
Description: Web Browser Page
Coverage: 9 percent



File: M3
Application: Microsoft Excel XP
Description: Excel Worksheet
Coverage: 15 percent



File: M4
Application: Microsoft PowerPoint XP
Description: PowerPoint slide
Coverage: 20 percent



File: M5
Application: Adobe Acrobat Distiller 5.0
Description: PDF v1.14 file (built from a Corel Draw 8.0 rendering.)
Coverage: 22 percent

Usable Pages

Usable pages are defined in this study as pages sufficiently devoid of imperfections such that they could be used in business communications. An unusable page is one that is "sufficiently flawed such that it would not be circulated to others as a business document and would only be acceptable as a draft page." [17] Many pages classified by QualityLogic as unusable had flaws beyond the minimum threshold of unusable, such as missing or illegible content.

[17] Reference 5

Page Usability as Defined by QualityLogic

QualityLogic tested cartridges using pages designed to be representative of real world printing and to allow for ease in identifying print quality flaws. The applications used and the page coverage are outlined in the table below.[18]

The test pages were sent to each printer in sequential order with the sequence repeated continuously. Print quality assessments were made at regular intervals throughout the life of the cartridges in the test.

Four aspects of print quality - legibility, resolution, definition, and uniformity - were observed for all pages that were printed. QualityLogic defined "usable" pages[19] as the combination of "Level 5" and "Level 4" printed pages, where:

- Level 5, a perfectly printed page, has "no apparent artifacts with the identifying rule of thumb being that a user would put this page in his or her resume" and
- Level 4 page "may have a minor flaw such as a speck or uneven graphic rendering but the average user would still use it in a typical business document."

Levels 3, 2, and 1 were placed into the "unusable page" category in which the page was "sufficiently flawed such that it would not be circulated to others as a business document and would only be acceptable as a draft page," the threshold for Level 3, or had lost legibility or content, Level 2 or 1, respectively. Appendix 6 provides examples of monochrome printed pages representing all five levels.

Page Usability Summary

This study relied on the quality and reliability testing conducted by QualityLogic. An average performance of all remanufactured cartridges tested was used in the baseline comparison, and is summarized in the table below.

Table 4: Page Yield and Page Usability: Baseline

	HP 96A	R 96A
Page Yield[20]	2,960 pages, the grand average of 50 cartridges tested in the LaserJet 2200 printer.	2,741 pages, the grand average of 30 cartridges each from six remanufactured brands in the LaserJet 2200 printer.
Usable pages (4+5)	2,837 pages	2,490 pages
Unusable pages (1+2+3)	123 pages	251 pages

[18] Note that because the QualityLogic tests included five different levels of coverage, the HP specifications in the appendix and here do not necessarily correspond.

[19] Reference 5. page 5.

[20] Data for page yield, usable, and unusable pages come from Reference 5.

A sensitivity analysis examined the effects of different thresholds of unusable pages, and the effects of QualityLogic's assumptions are addressed in detail in the data quality section.

The cartridge user's "unusable pages" were modeled as put into a recycled paper bin and not added to the Total Waste impact category (the increase in waste due to unusable pages is associated with the waste inherent in paper production). The impacts of paper recycling were examined for the model, however, since these impacts to both of the cartridge models were very small (less than 0.5 percent), they were not included in the final analysis.

Electricity for Printing

Printing paper for both cartridges required 393 Watts of electricity at the rate of 18 pages/minute (220 Volt model).[21] Only electricity for printing was accounted for in the use stage; printer sleep mode and other possible printer impacts independent of the use of the cartridge were excluded. Electricity consumed by the printer is directly proportional to the number of pages printed, so electricity use will increase with the number of unusable pages printed.

Paper Modeling

The paper used for both cartridges was modeled as 20-pound office paper (80 g/m^2), with a standard post-consumer recycled contents, i.e., 30 percent recycled fibers.

The data for the virgin fibers paper production model are mid-1990's data derived from a European plant that produces Kraft from pulp bleached with sulfate,[22] and is considered to be representative of the Kraft process.[23] The recycled paper data, also from the mid-1990s, come from one European plant that produces recycled paper using de-inked wastepaper and pulp bleached with sulfate.[24] Transportation to the end user is included in both paper models.

These paper data sets are updated versions of the data in Reference 4, but overall this updated data has not changed significantly from the original in terms of the energy/materials used and the environmental emissions. This is consistent with standard paper industry practice; paper production processes have not changed significantly over the past 10 years.[25] A scenario analysis modeling the use of 100 percent recycled fiber paper was also performed to highlight how results were affected when using a perceived "best-case" paper scenario (see page 39).

User Behavior

For this study, unusable pages were assumed to be recycled and the pages were then reprinted by the user on a new sheet of paper. Reprinting was assumed to occur on a 1:1 basis. In other words, it was assumed that each unusable page resulted in exactly one reprint. An actual user may consume more or less paper; for example, a user could also accept, or not notice, a low quality page. However, it is also possible that a user might discard and reprint an entire multi-

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[21] HP website.

[22] BUWAL (Bundesamt für Umwelt, Wald und Landschaft) n°250, Band II: Ökoinventare für Verpackungen, Bern, 1996, pages 210-11.

[23] Telephone interview with International Paper contact, March 2004.

[24] BUWAL (Bundesamt für Umwelt, Wald und Landschaft) n°250, Band II: Ökoinventare für Verpackungen, Bern, 1996, pages 238-39.

[25] Telephone interview with International Paper contact, November 2003.

page document because of a single low quality page - magnifying the impact of unusable pages.

End of life

End of life refers to the fate of the cartridge after toner depletion. The baseline end-of-life models are described below.

HP 96A End of Life

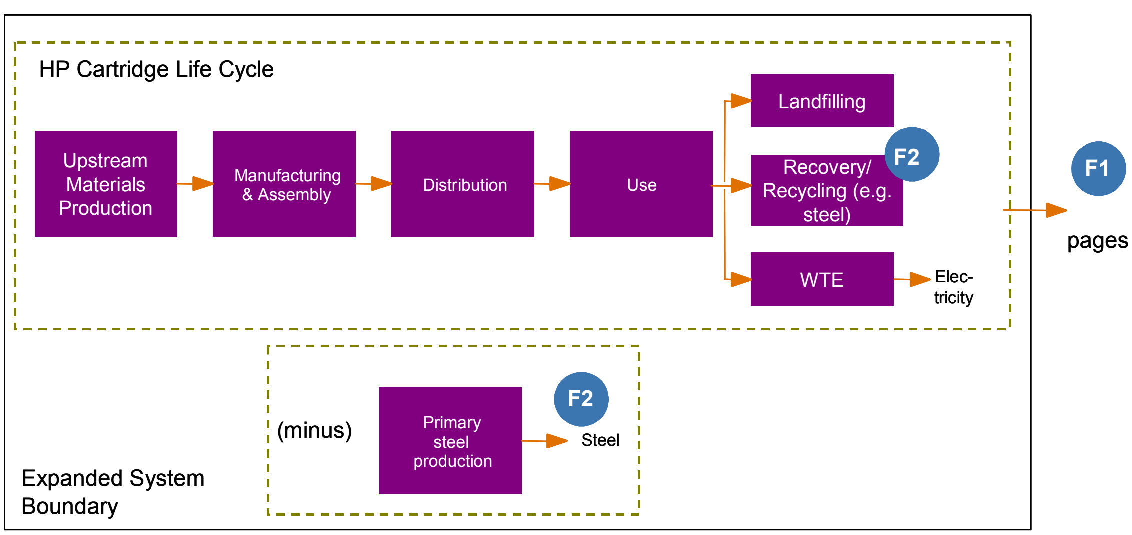
The HP 96A cartridges include a return-mailing label. Customers have the option to return a used cartridge for recycling individually (in the replacement cartridge box), or in bulk boxes, which can be ordered over the Internet. This model considers only individual mailers. As the intent of this model is to instruct purchasing and policy decisions regarding cartridge alternatives available to the consumer, it was assumed that the user choosing HP cartridges would take advantage of the free return and recycling program after each use, if not providing the cartridge to a remanufacturer.

Recycling for U.S. customers is conducted at a facility in Gloucester, Virginia**.** Transportation from the use location (central U.S.) is modeled as diesel truck. The Gloucester operation was modeled as recovering all metals, and utilizing plastic resins for energy recovery at a waste to energy (WTE) facility. Modeling for both of these is described below. Process impacts were not considered. In 2003, the HP toner cartridge recycling program sent no material to landfill (2004 HP Global Citizenship Report).

Metals Recycling for HP 96A

Recycling was modeled using system boundary expansion, as shown in Figure 4. When components of the cartridge at the end of its life are recycled, the model subtracts out the primary production impacts for that quantity of material being recycled. In other words, if 1 kg of steel is recycled, then in the model, the inventory from the production of 1 kg of virgin steel is subtracted from the model to provide a 'credit' for recycling.

Figure 4: Metals Recycling Modeling for HP 96A

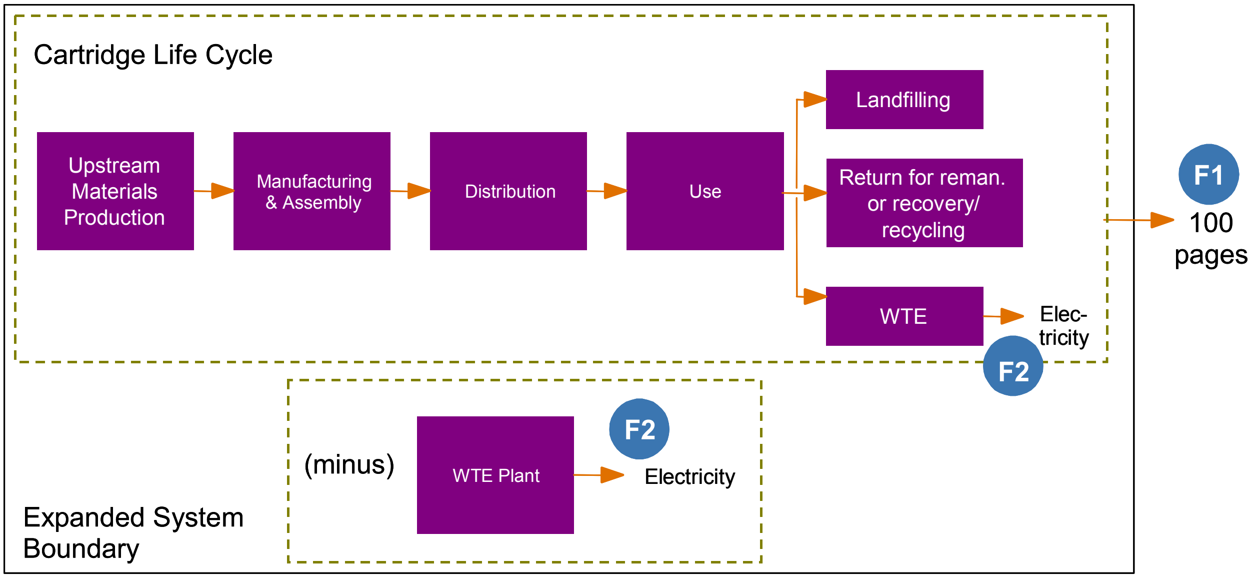


F1 = primary function = printing 100 usable pages
F2 = secondary function = displacing primary production of a material

WTE Modeling for HP 96A

At a WTE plant, the energy produced is either sold to the electricity grid or used directly by a facility. An LCA can only quantify a system based on one function (in this case, the function of printing 100 usable pages). Since a new function, electricity production, has been introduced, that function must be subtracted out of the system. This is handled by expanding the system boundaries, shown in the figure below, in which the WTE plant producing electricity is being subtracted out of the system.[26]

Figure 5: WTE Modeling for HP 96A



F1 = primary function = printing 100 usable pages
F2 = secondary function = production of electricity

R 96A End of Life

As was described previously, the OPC drum at its end of life was recycled and the balance of the cartridge was sent to a landfill and WTE facility, according to local waste management practices. The impact of the quantity disposed of in a landfill was accounted for in inventory results solely as solid waste, with no additional impacts from landfilling (e.g., seepage from a landfill or methane emissions or recovery). This assumption is consistent throughout the model, regardless of the cartridge type. The sensitivity analysis looks at the metals recycled at the remanufactured cartridge's end of life.

Basis for the baseline remanufactured cartridge end-of-life assumptions.

While published information about the recycling practices of remanufacturers is limited, remanufacturers do not appear to have a recycling capability for end-of-life cartridges. However, there is evidence to support the assumption that a remanufactured cartridge will go to the MSW stream instead of being recycled at end of life. HP, which has a return and recycling program, periodically receives requests from remanufacturers for recycling services, suggesting that remanufacturers do not have cartridge recycling capability. Trade publications refer to large

[26] According to ISO 14041 Section 6.5.3, allocation should be avoided by expanding the product system to include the additional functions related to the coproducts.

percentages of remanufactured cartridges being "abandoned."[27] Additionally, a number of cartridge brokers publish disposal fees for previously remanufactured (so-called "non-virgin") and damaged cartridges.[28]

Other Remanufactured Cartridge Scenarios

Two other cartridge life cycle scenarios were examined. As earlier discussed, these are not actual existing cartridges but theoretical cartridge scenarios of those that exist in the marketplace. These are described below.[29]

- International Operation – The intent of this scenario was to model a remanufacturing operation that is considered technically sophisticated and produces cartridges in a location that services multiple international markets. These cartridges usually include OPC drum replacement and represent the high-end of reliability and print quality consistency among remanufactured brands, as observed in the QualityLogic study.[30]
- "Drill and Fill" Operation – The intent of this scenario was to model a remanufacturing operation that has the least intensive form of processing, and yields the low-end of reliability and print quality consistency observed in the QualityLogic study.[31]

International Operation

As the cartridge remanufacturing industry has matured, "a very limited number of rechargers now provide a very high percentage of the industry's reconditioned compatible toner cartridges."[32] Many of the larger remanufactures have production facilities in developing nations where labor costs are low, including Asian countries. This scenario modeled a cartridge remanufacturing operation located in Thailand.

The operation was modeled as technically sophisticated, with OPC drum replacement and high-end of quality/reliability observed among remanufactured brands in the QualityLogic study. To model conditions in a developing country, no recycling of the replaced OPC drum and no end-of-life recycling was assumed.

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[27] Golden, Chad. "Worth Their Weight in Gold, Mining for Cartridge Core Profitability." Imaging Spectrum. August 2002. pp 25-30.

[28] See for example, http://www.rcrimaging.com/empty_toner.htm; http://www.proton.fr/ ;and http://www.brokers-international.de/german/preise/general.html

[29] To reiterate, these are not meant to be actual existing cartridges but theoretical cartridges that may exist in the marketplace.

[30] For the purposes of this study, "high-end of quality/reliability" was defined as the cartridge with the highest percentage of usable pages.

[31] For the purposes of this study, "low-end of reliability and print quality consistency" was defined as the cartridge with the lowest percentage of usable pages.

[32] Katun Corporation, "A Brief History of Toner Cartridge Remanufacturing." http://www.katun.com/downloads/historytonercart3152.pdf. 2001

Drill and Fill Operation

Although over time fewer manufacturers are using "drill and fill" processes, companies that utilize this remanufacturing method still exist.[33] As the name suggests, this procedure involves drilling a hole in the cartridge to replenish toner. No parts are replaced. This scenario was modeled as a local operation, with minimal transport distances. A high sort and discard rate was modeled as it is expected that only a limited portion of collected cartridges will stand up to additional usage with no parts replacement, without severe quality/reliability impacts.

This scenario was modeled with the low-end of reliability and print quality consistency observed in the QualityLogic study. It should be noted that the QualityLogic study targeted leading remanufactured brands, which typically do not practice drill and fill processing. Thus the performance of cartridges measured by QualityLogic, even the worst among major remanufactured brands, is likely superior to a drill and fill operation. This makes the quality/reliability and yield assumptions for this scenario conservative.

Typically, a local operation that would employ drill and fill would not have an end-of-life recycling solution for processed cartridges. This scenario models the entire cartridge as going to the MSW stream. The table in the next section includes the summary of the modeling for both of these scenarios.

[33] Katun Corporation, "A Brief History of Toner Cartridge Remanufacturing." http://www.katun.com/downloads/historytonercart3152.pdf. 2001

Summary of Cartridges Compared

Table 5 summarizes the modeling details of the baseline cartridges and the two remanufactured cartridge scenarios.

Table 5: Summary of all "96A" Cartridge Scenarios (Europe)

		Baseline HP 96A	Baseline R 96A	International Operation	Drill and Fill
Production	**Upstream materials production**	99.5 percent of the raw materials in the Parts and Materials List	Some material impacts as the OPC drum is replaced. Replaced OPC drum is sent to a landfill (86 percent) and WTE plant (14 percent).	Some material impacts as the OPC drum is replaced. Replaced OPC drum is sent to a landfill (86 percent) and WTE plant (14 percent).	No material impacts as the cartridge is recovered. No materials are replaced except for the toner.
	Transportation to manufacturing and assembly	Materials transported 300 miles by truck to the place of manufacture.	Remaufacturing within the same region as the user. Transported 1,500 miles by truck to the remanufacturing plant from the end user in Central North America (St. Louis, MO).	International remanufacturing. Transported approximately 1,400 miles by truck (to CA) and 8,000 miles by sea to the remanufacturing plant in Thailand from the end user in St. Louis	Local remanufacturing. Transported 100 miles by truck to the remanufacturing plant from the end user in St. Louis.
	Manufacturing and assembly	Limited process data (i.e., injection molding for the plastic components, which represent 40 percent by mass, was included. The balance of assembly impacts was not.	Limited process data. Sort & discard rate: 20 percent. Those cartridges are sent to a landfill (86 percent) and WTE plant (14 percent).	Limited process data. Sort & discard rate: 20 percent. Those cartridges are sent to a landfill (86 percent) and WTE plant (14 percent).	Limited process data. Sort & discard rate: 50 percent. Those cartridges are sent to a landfill (86 percent) and WTE plant (14 percent).
	Packaging	See Table 3	See Table 3	Same as R 96A baseline	Same as R 96A baseline

		Baseline HP 96A	Baseline R 96A	International Operation	Drill and Fill
Distribution	**Distribution to end user**	Transported 5,200 miles by sea and 1,400 miles by truck to the end user in St. Louis, MO from Japan	Transported 1,500 miles by truck to the end user in St. Louis.	Transported 8,000 miles by ship and 1,400 miles by truck to the end user in St. Louis from the remanufacturing plant in Thailand.	Transported 100 miles by truck to the end user in St. Louis
Use	**Printing**	Print mode power consumption: 393W (220 Volt model)	Print mode power consumption: 393W (220 Volt model)	Same as R 96A baseline	Same as R 96A baseline
	Page yield[34]	2,960 pages, the average of 50 HP 96 A cartridges tested in the QualityLogic study.	2,741 pages, the grand average of 30 cartridges each from six 96A model remanufactured cartridge brands (180 cartridges total) tested in the QualityLogic study.	2,428 pages, the average of 30 cartridges tested from the high-end performing 96A model remanufactured cartridge brand in the Quality Logic study.	2,283 pages, the grand average of 30 cartridges tested the low-end performing 96A model remanufactured cartridge brand in the QualityLogic study.
	Number of unusable pages[35]	123 pages, the average of 50 HP 96A cartridges tested in the QualityLogic study.	251 pages, the grand average of 30 cartridges each from six 96A model remanufactured cartridge brands (180 cartridges total) tested in the QualityLogic study.	143 pages, the average of 30 cartridges tested from the high-end performing 96A model remanufactured cartridge brand in the QualityLogic study.	405 pages, the average of 30 cartridges tested the low-end performing 96A model remanufactured cartridge brand in the Quality Logic study.
	Paper type	20 lb. paper, with a recycled content of 30 percent.	20 lb. paper, with a recycled content of 30 percent.	Same as R 96 baseline	Same as R 96 baseline
End of Life	**End of Life**	Metals are recycled, the remaining cartridge is sent to a waste-to-energy plant; transportation of 2,500 miles by truck is accounted for.	The OPC drum is recycled, and the remaining cartridge is sent to a landfill (86 percent) and WTE plant (14 percent) ; transportation is accounted for.	The cartridge is sent to a landfill (86 percent) and WTE plant (14 percent) ; transportation is accounted for.	The cartridge is sent to a landfill (86 percent) and WTE plant (14 percent); transportation is accounted for.

[34] Reference 5

[35] Reference 5

Section 4

Sensitivity Analysis

In order to better understand the dynamics of the R 96A scenarios and the sensitivity of certain model parameters, the baseline scenario was run with the parameter changes in Table 6. The impacts of these changes are outlined in the results sections.

Table 6: Sensitivity Analysis Checks (North America)

Changes to Cartridges Separately	
What from the baseline is assessed	**What is changed in the cartridge model(s)**
HP's recycling program Baseline: HP 96A metals are recycled and remainder goes to WTE plant	HP cartridge goes into MSW stream (86 % to landfill and 14% to WTE plant) at EOL.
Transportation/distribution Baseline: R 96A is remanufactured regionally (500 miles)	R 96A is remanufactured locally (100 miles) R 96A is remanufactured overseas
Waste at remanufacturing Baseline: R 96A "sort and discard" rate is 20 percent	Low remanufacturing "sort and discard" rate (0 percent) High remanufacturing "sort and discard" rate (50 percent)
Material replacement in the R 96A Baseline: the OPC drum is replaced	No materials are replaced in the R 96A All materials except the housing are replaced in the R 96A
Fate of the replaced OPC drum Baseline: goes into the MSW stream	Used OPC drum is recycled Used OPC drum is landfilled
Printing performance of R 96A Baseline: grand average of the QualityLogic tested remanufactured cartridges (see Table 5)	High-end performing R96A brand from the QualityLogic study is applied Low-end performing R96A brand from the QualityLogic study is applied
End of life waste management of the R 96A Baseline: the R 96A OPC drum is recycled and the rest goes into the MSW stream	All metals in the R 96A are recycled The entire R 96A is landfilled

Changes to both cartridges	
Total page yield Baseline: 2,960 pages and 2,741 pages for the HP 96A and R 96A, respectively	HP 96A page yield: scaled up to the HP 96A specification of 5,000 pages R 96A page yield: scaled up to 4,630 pages, the HP specification adjusted for R 96A's reliability "Usable" and "unusable" pages are scaled up using the same rate
Use of different grade of paper Baseline: 30 percent recycled and 70 percent virgin fibers	Models are run using 100 percent recycled paper instead of 30 percent recycled.
Page usability threshold levels	
HP 96A unusable pages Baseline: Page yield: 2,960 pages, with reject levels 1+2+3 = 123 pages	Page yield: 2,960 pages (baseline) Reject levels 1+2 = 78 pages Reject level 1 = 60 pages
R 96A unusable pages Baseline: Page yield: 2,741 pages, with reject levels 1+2+3 = 251 pages	Page yield: 2,741 pages (baseline) Reject levels 1+2 = 164 pages Reject level 1 = 129 pages

Section 5

Results and Discussion

The life cycle impact assessment results for the baseline comparison and remanufactured cartridge scenarios are presented below in terms of their functional unit of 100 usable pages printed. The life cycle inventory tables are found in Appendix 7.

Comparisons of the Baseline and Remanufactured Scenarios

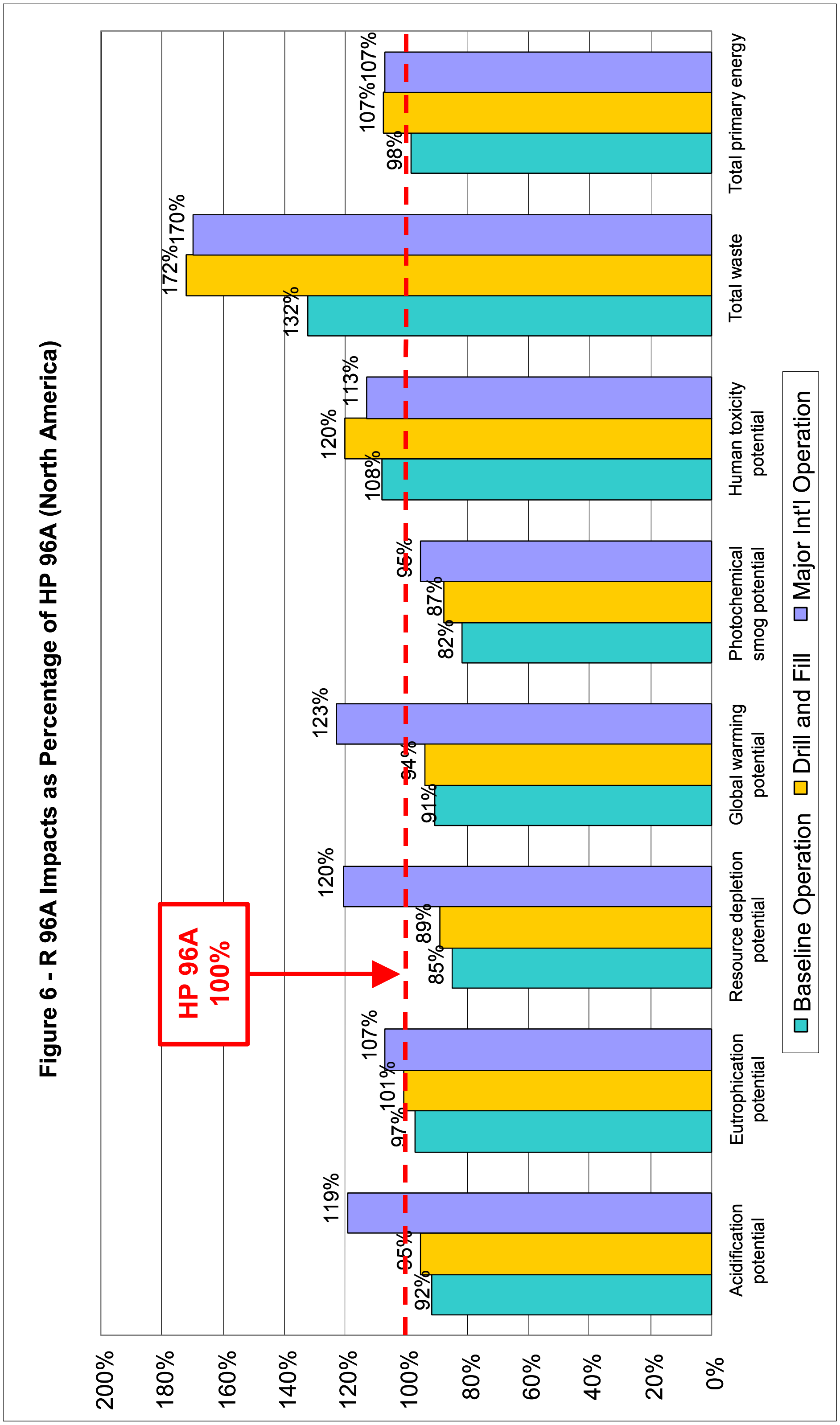
Overall Life Cycle Results

Table 7 presents the overall life cycle impact assessment results of the HP 96A in comparison to the baseline, the "drill and fill," and "international operation" R 96A cartridges. Figure 6 portrays the information in terms of percentage in relation to the originally manufactured HP cartridge.

Table 7: Overall Life Cycle Impact Assessment Results (North America)

	HP 96A Baseline	R 96A Baseline	R 96A Drill & Fill	R 96A Intl. Operation
Acidification potential (g eq. H+)	0.15	0.14	0.15	0.18
Eutrophication potential (g eq. PO4)	0.88	0.85	0.88	0.94
Resource depletion potential (MJ surplus)	0.97	0.82	0.86	1.16
Global warming potential (g eq. CO_2)	570	517	534	699
Photochemical smog potential (g eq. ethylene)	0.50	0.41	0.44	0.48
Human toxicity potential (DALYs)	8.9 E-8	9.5 E-8	1.1 E-7	1.0 E-7
Total waste (kg)	0.09	0.12	0.15	0.15
Total primary energy (MJ)	29.8	29.4	32.0	31.9

Figure 6: R 96A Life Cycle Impact Assessment Results as a Percentage of HP 96A (North America)



The following are general remarks on the overall results. The contribution analyses and sensitivity analyses are more instructive as to the driving parameters of each system.

Remarks

- R 96A Baseline – The baseline R 96A impacts are within 20 percent of the HP 96A – many within 10 percent – with some R 96A impacts less and some greater than corresponding HP 96A impacts. The baseline scenario cartridges may be considered at parity with each other (*see note below).
- Drill and Fill scenario – All of the impacts for the drill and fill scenario are at parity with the HP cartridge, with the exception of waste (almost 50 percent worse). As a general statement, the lower quality cartridge impacts offset the fact that no components were replaced at the remanufacturing plant except the toner.
- International Operation scenario – The HP cartridge is at parity with the international scenario for all of the impacts, mainly due to the large transportation distances. Also, despite the higher printing quality modeled for this scenario, the lower page yield associated with this cartridge somewhat offsets the benefits of quality. This point is discussed later on in the sensitivity analysis.

* Note: In LCA, uncertainties in each model come from unit processes within each life cycle stage and are related to data quality issues inherent in LCA, assumptions made, and other data considerations. Aggregating and compounding the individual stages into a full life cycle system can result in quite a significant margin of error, up to +/-30 percent or beyond, and unfortunately, there is no simple way to calculate this. But given the inherent uncertainties in LCA, the results observed in this model are remarkably close.

* It is also important to note that since there are uncertainties on both sides of the comparison, the relative difference of the options should be the focus, not the numbers themselves.

Contribution Analysis of the Baseline and Remanufactured Scenarios

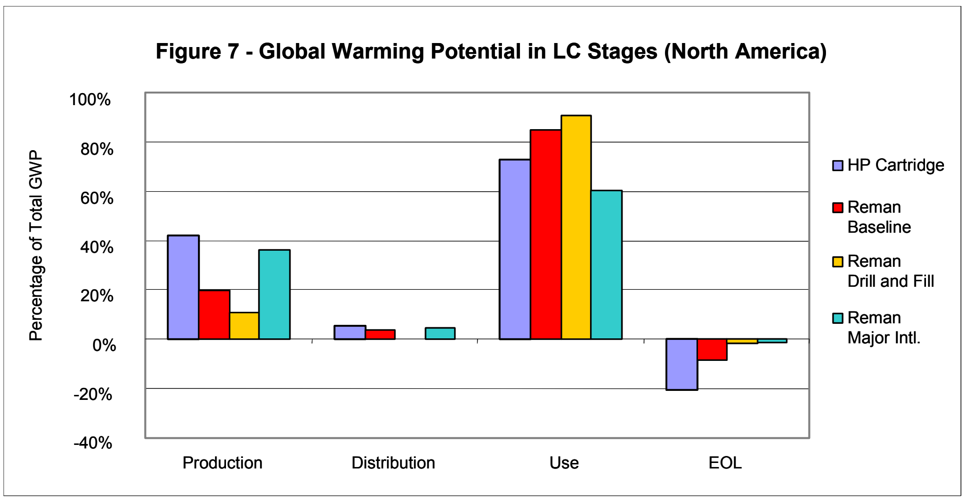
GWP and total waste were used to demonstrate the contributions of each life cycle stage. Waste was chosen since it is considered to be at the core of the comparison, and GWP was used because of its globally accepted methodology and its use as an indicator not only of climate change potential but also of the fuel energy in a system.

Global Warming Potential

Table 8: Contribution Analysis – GWP (North America, expressed as grams per CO_2 gram equivalents)

	Total LC	Production	Distribution	Use	EOL
HP Cartridge	570	239	31	415	-116
Reman - Baseline	517	103	19	438	-42
Reman - Drill and Fill	534	59	2	483	-9
Reman - Major Int'l Operation	699	252	32	422	-8

Figure 7: Contribution Analysis – GWP
(Impact from generating 100 usable pages; data is specific to North America LCA model)



Remarks

- Production – The 36 percent production impacts of the international operation are due to not only the production of a replacement for the used OPC drum, but also the transport of the used cartridge from the U.S. to the remanufacturing plant in Asia. The production impacts for HP would be more significant if the cartridge were not recycled at the end of life. Not surprisingly, the R 96A baseline and drill and fill operation do not have high impacts at production since the former replaces only the OPC drum, and the latter does not replace any additional components, and no impacts were assumed for disassembly and assembly.
- Use – For all of the cartridges except the international operation, the use stage makes up over 75 percent of the life cycle impacts.
- Distribution – Distribution from the point of manufacture to the user contributes very little to the life cycle. Even the foreign transportation contributes only 5 percent to the foreign operation.
- End of Life – The higher negative end of life number for HP comes from its recycling program. The higher baseline remanufactured cartridge's end of life number comes from

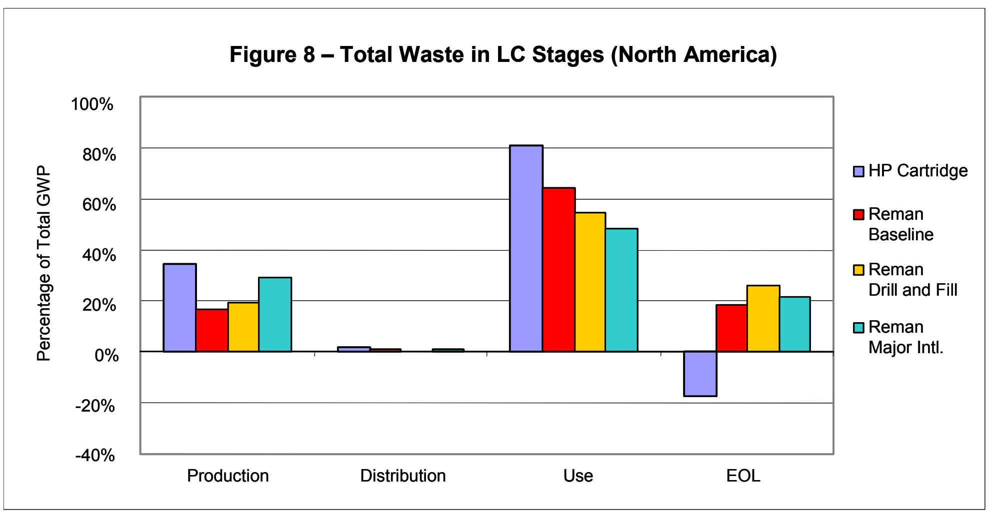
the OPC drum being recycled, and the other negative numbers stem from the WTE plant in the MSW management stream assumed for the North American model. Negative results at end-of-life stage on charts indicate the net benefits gained from recovery of materials or energy for beneficial use. Percent totals may appear to exceed 100 percent where cartridge recycling or energy recovery programs offset portions of total impact.

Waste

Table 9: Contribution Analysis – Total Waste (North America, expressed in kilograms)

	Total LC	Production	Distribution	Use	EOL
HP Cartridge	0.08	0.03	4.0 E-5	0.07	-0.01
Reman - Baseline	0.10	0.01	1.3 E-5	0.07	0.01
Reman - Drill and Fill	0.12	0.02	3.3 E-6	0.08	0.02
Reman - Major Int'l Operation	0.12	0.03	4.0 E-5	0.07	0.02

Figure 8: Contribution analysis – Total Waste (Impact from generating 100 usable pages; data is specific to North America LCA model)



Remarks

- Production – Waste from production consists of several elements: waste during the production of the cartridge materials, sort and discard waste at the remanufacturing plant, and the parts replaced at the remanufacturing plant that are sent to the landfill.
- Use – For the HP 96A, while it seems that the use stage makes up 81 percent of the total, the offset from metals recycling at end of life affects the calculation. Otherwise, the use stage generally lies in the 60-75 percent range for all of the options.

- End of Life – The end-of-life waste for the remanufactured cartridge scenarios is due to the cartridges in the MSW stream, and HP's negative end-of-life waste is derived from the credit from recycling metals. Negative results at end-of-life stage on charts indicate the net benefits gained from recovery of materials or energy for beneficial use. Percent totals may appear to exceed 100 percent where cartridge recycling or energy recovery programs offset portions of total impact.

Sensitivity Analysis

Using the baseline HP 96A and R 96A cartridges, single parameters were adjusted to assess the model's sensitivity to these values and to better understand the extent to which each change can drive the results. Figures 9-12 portray the results of the single-parameter sensitivity analysis, using the global warming potential and waste impact indicators.

Each of the following were analyzed as individual changes (Figures 9 and 10):

- HP cartridge in the MSW stream (landfilled at end of life)
- Local vs. overseas remanufacture of the R 96A
- Low vs. high remanufacturing "sort and discard" rate (0 percent vs. 50 percent)
- No parts replacement vs. total parts replacement (all except housing) in the R 96A
- Replaced OPC drum recycled vs. landfilled
- High-end vs. low-end performing cartridge (in terms of usable pages per total yield)
- At the end of life of the remanufactured cartridge, metals are recycled vs. whole cartridge landfilled

The following were analyzed for both baseline cartridge options (shown in Figure 11 and Figure 12):

- Page yield of cartridges scaled up according to the HP 96A specification of 5,000 pages
- 100 percent recycled paper used for printing

Finally, a sensitivity analysis was conducted on page usability thresholds to address the subjectivity of the person printing and accepting pages of varying quality (Figure 14 and Figure 15). The levels of rejection are presented again in Table 10.

Table 10: Page Usability Thresholds

Page Usability Levels	
HP 96A unusable pages Baseline: Page yield: 2,960 pages, with reject levels 1+2+3 = 123 pages	Page yield: 2,960 pages (baseline) Reject levels 1+2 = 78 pages Reject level 1 = 60 pages
R 96A unusable pages Baseline: Page yield: 2,741 pages, with reject levels 1+2+3 = 251 pages	Page yield: 2,741 pages (baseline) Reject levels 1+2 = 164 pages Reject level 1 = 129 pages

HP cartridge landfilled at end of life

Since the metals are not recycled, there is no beneficial offset from production of the initial aluminum and steel in the system. In addition, since the remaining materials are not incinerated in this scenario, there are no offsets from energy production at a WTE plant.

- GWP – GWP increases about 20 percent when the HP cartridge at end of life is placed in the MSW stream.
- Waste: Total waste increases by almost a third when the cartridge at end of life is placed in the MSW stream.

Local vs. overseas remanufacture of the R 96A

Impacts are directly related to transportation, which is affected in two stages of the life cycle: from the user to the remanufacturing plant and from the remanufacturing plant back to the user.

- GWP – GWP is hardly affected with the local remanufacturing scenario since the baseline distance is in same magnitude as the scenario (500 miles transported vs. 100 miles transported). With foreign remanufacture, transportation impacts are more significant due to the greater distance traveled.
- Waste – There is almost no change for either option.

Low vs. high "sort and discard" rate (0 percent vs. 50 percent)

Impacts are due to transporting the unsuitable cartridges and disposing of them into the MSW stream.

- GWP – GWP is hardly affected when the higher rate of unusable cartridges are transported to the remanufacturing facility.
- Waste – This category is clearly more sensitive to the rate of cartridge selection and discarding.

No materials vs. all (except housing) replaced in the R 96A

When the components are replaced, the impacts of production are included in the model.

- GWP – Not surprisingly, as more materials are replaced, GWP (indicating energy use) increases. The R 96A baseline of replacing only the OPC drum seems to be a natural median point for GWP.
- Waste – Total waste in the system is not as sensitive to the difference/quantity of materials produced.

Fate of used OPC drum: recycled vs. landfilled

The system benefits only slightly when the aluminum OPC drum is recycled, due in large part to the small amount of aluminum in the drum. Waste is affected even less.

High-end vs. low-end performing cartridge (in terms of usable paper per total yield)

The use stage performance of the cartridge is dependent on the number of unusable pages and the total yield. The modeling assumptions were based on the remanufactured cartridges with the high-end and low-end ratio of unusable to usable pages from the QualityLogic results. The high-end QualityLogic performer had a much better ratio but had a lower yield (see Table 5).

- GWP – Based on the ratio and yield, the best performing cartridge did not improve the GWP much from the baseline remanufactured cartridge, which had a low-end ratio but high-end overall page yield. The lowest performer caused an increase in GWP.
- Waste – This impact category is affected mainly because of the waste produced during paper production.

At the end of life for the remanufactured cartridge, metals are recycled vs. whole cartridge being landfilled

This scenario shares the same comments as the HP recycled at end of life vs. landfilled. The difference from baseline (467 g. eq.) to all metals recycled (415 g. eq.) is because all metals are being recycled as opposed to just the OPC drum.

Note:

On the following pages, the first and second bar in each set corresponds to the first and second sensitivity point mentioned underneath in each X-axis point graphed. The darker gold and dark teal bars signify the baselines of the HP and remanufactured cartridges, respectively, and the subsequent lighter gold and light teal bars are the corresponding sensitivity analysis results.

Figure 9: GWP: Individual Parameters Sensitivity Analysis

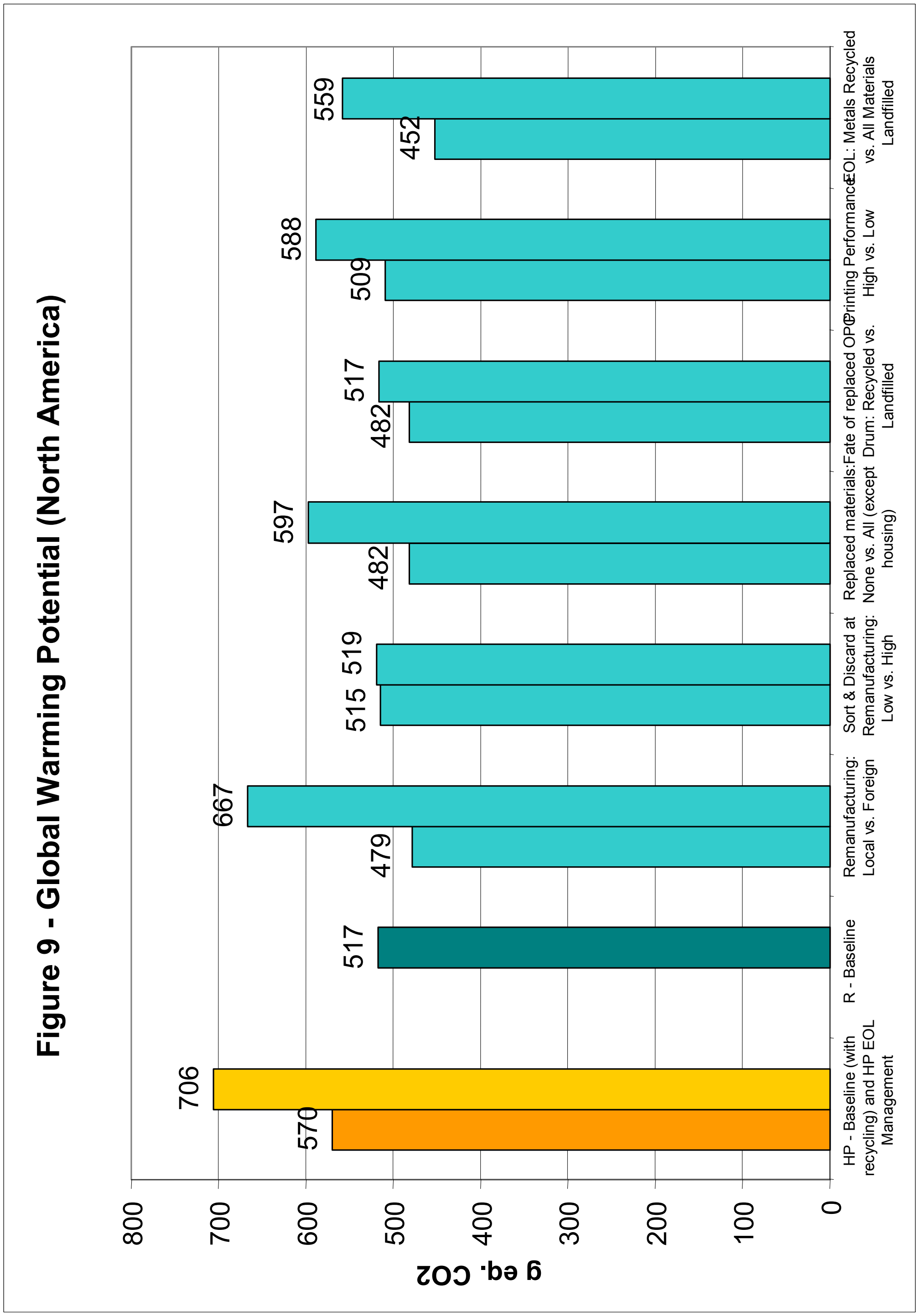
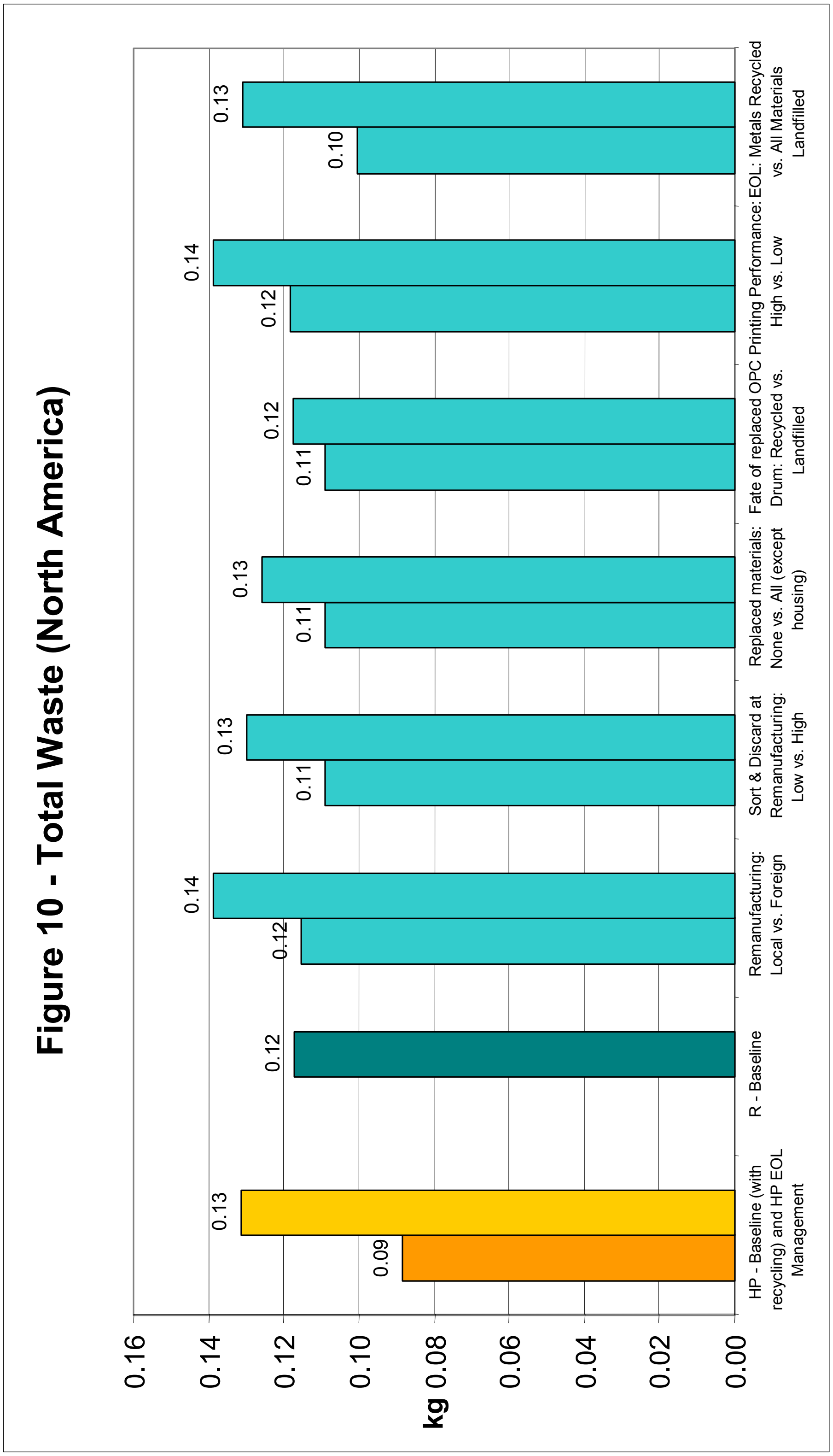


Figure 10: Waste: Individual Parameters Sensitivity Analysis



Page yield scaled up: HP vs. Reman

When page yield is scaled up according to the HP 96A specification of 5,000 pages and the functional unit of 100 printed pages is still applied, all life cycle stage impacts, spread out over the larger page yields, decrease while the use stage stays the same (see Figure 13). This is because while the same amount of resources are required to generate the 100 useable pages during use, a corresponding smaller portion of cartridge environmental impacts during the other stages are apportioned as the given cartridge generates more functional units. Since the use stage is still one of the largest drivers of the model, the resulting total impacts decrease to some extent per models: overall GWP for the HP 96A decreases about 10 percent while the R 96A decreases about 4 percent. Waste for the R 96A is more sensitive, about 12 percent less than the baseline. While not a large decrease in overall life cycle, a higher page yield offers a way to minimize the life cycle impacts produced in other parts of the supply chain, on a per functional unit basis.

100 percent Recycled Paper: HP vs. Reman

Surprisingly, waste increases quite significantly for both cartridges with the use of 100 percent recycled paper. This is because recycled paper production generates much more waste when comparing, pound for pound, recycled vs. virgin paper production. GWP decreases significantly at about the same rate for both cartridges.

Figure 11: GWP Scenarios Affecting Both Cartridges (HP page yield per 5,000 spec)

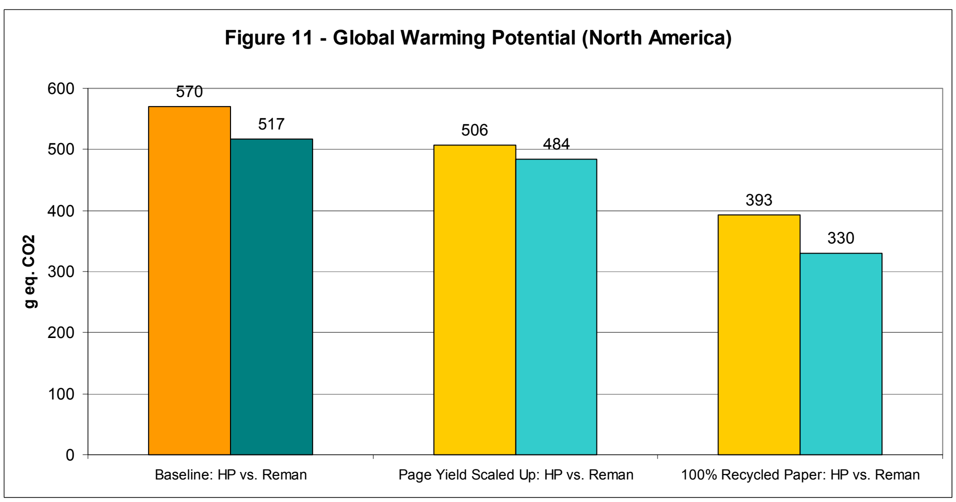


Figure 12: Total Waste Scenarios Affecting Both Cartridges

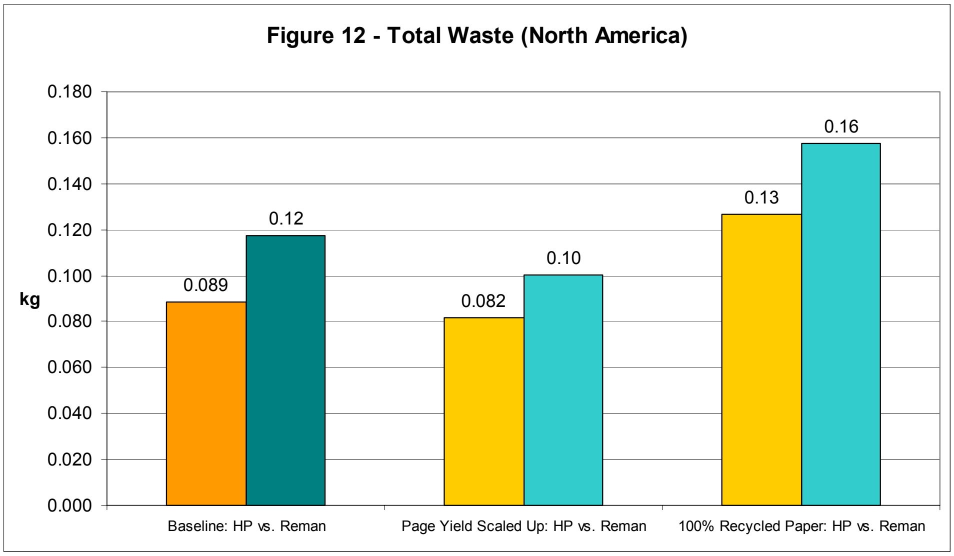
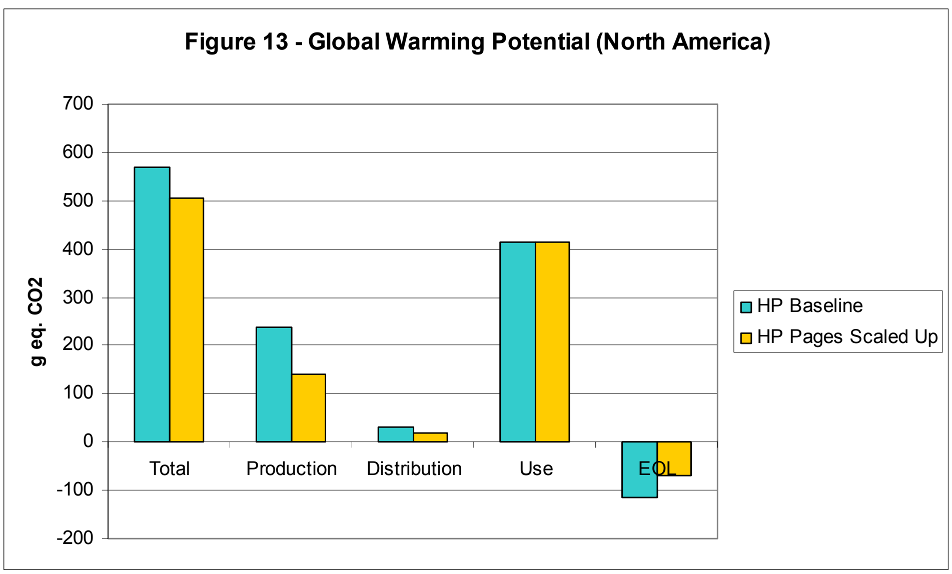


Figure 13: Effects Over the Life Cycle of Page Yield Increase



Page Usability Thresholds

The results of the analysis below demonstrate that the model is hardly affected even when the user retains all of the printed pages, except the most illegible. Average model results change less than 5 percent in response to changing the threshold for rejecting a page from QualityLogic's rating of Level 3 to Level 2, and even to Level 1. Changing the threshold to Level 1 (far right points on Figures 14 and 15, titled “2+3+4+5”) would mean that only pages with lost content would be discarded as unusable. This lack of sensitivity demonstrates that QualityLogic’s observations were not biased to pages with only minor defects. Indeed a significant number of pages which QualityLogic classified as unusable had major quality defects, such as lost or illegible content (see QualityLogic printed page samples in Appendix 6).

Figure 14: GWP: Page Usability Assessment

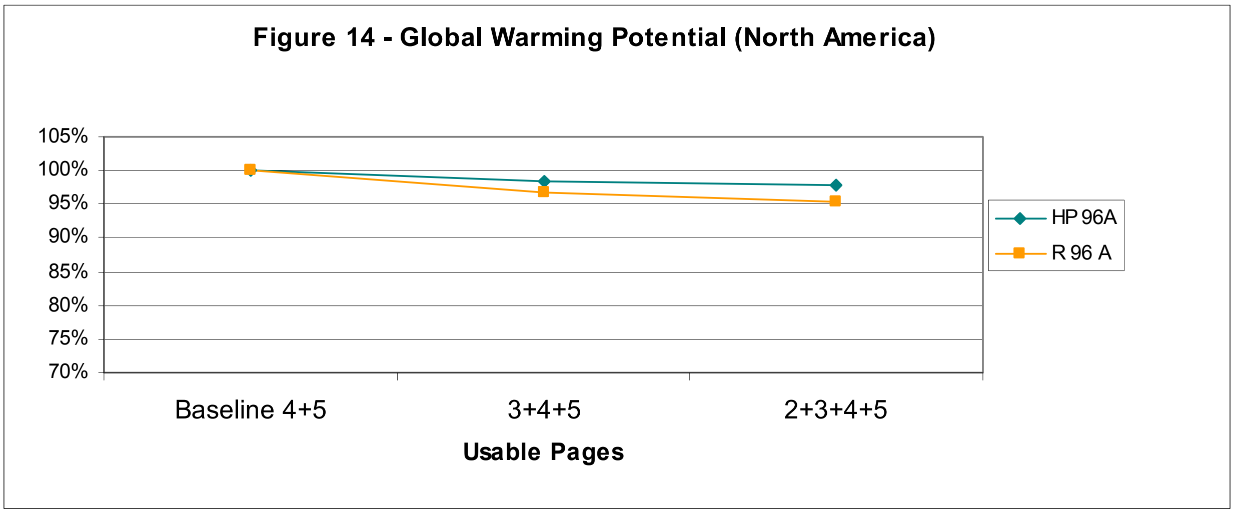
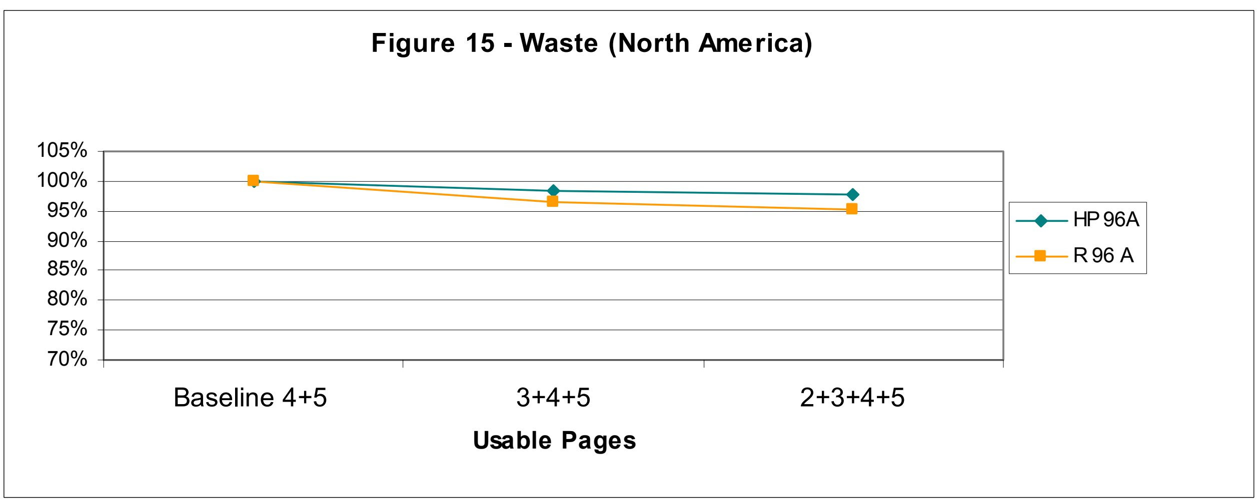


Figure 15: Waste: Page Usability Assessment



Section 6

Limitations and Data Quality

Understanding the Modeling and Limitations of the Study

Cartridge Modeling

The model was built using the current HP 96A Parts and Materials List (Reference 5) with only limited part manufacturing data (e.g., process energy). In LCA studies, using only a bill of materials (the Parts and Materials List in this case) for the production stage of a product model is a common and accepted practice, especially where no other data are available. This approach is often used because collection of process data is either impractical or impossible because of confidentiality, time, or inaccessibility.

However, wherever possible, publicly available processing data was applied. For example, injection molding of plastics, which represent 40 percent of the mass of the cartridge, was included. And since both cartridges lacked process impacts, this data gap is mitigated, since relative, not absolute, impacts are important when making a comparison. While there is precedent to suggest that cartridge manufacturing may have a smaller contribution to the product's life cycle than the upstream raw material production, there is not enough data to confirm this. Nevertheless, the study has shown that much of the environmental impacts are driven by features/performance of the cartridges during their use (see tables 9 and 10).

The model for the production of the HP 96A cartridge is a valid LCA model, based on the following points:

- The model follows the ISO guidelines for LCA -- The current model accounts for over 99.5 percent of the mass of materials in the cartridge (including the manufacture of 40 percent of the mass of the cartridge), plus toner and packaging materials. The bill of materials provided by HP (in the parts and materials list) accurately reflects the composition of the 96A toner cartridge.
- The model is both comprehensive and conservative – Over 99 percent of the components listed in the Parts and Materials List are included – this is a more comprehensive approach than HP's 1998 toner cartridge study, which included only the top 90 percent by mass of the bill of materials. Finally, none of the LaserJet cartridge components were modeled as containing recycled material, while some non-image producing component recovery does occur in the HP LaserJet cartridge recycling program. The only exceptions to this were some of the cartridge's packaging materials and the post-consumer recycled portion of the paper included in the use stage model.

QualityLogic Study

This study places a significant reliance on the results of the QualityLogic report commissioned by HP, which provided a wealth of empirical data on cartridge performance. For the LCA, a representative model of remanufactured cartridge performance was developed, based on data from the QualityLogic study. As such, it was necessary to average some of the collected data to produce a generic profile. Included in the average sample, the remanufactured brands were those most representative of the remanufactured cartridge business model.

One limitation of this approach is that the market share of the remanufactured products that were tested was not provided in the QualityLogic study. QualityLogic attempted to include the larger brands that represented leading worldwide remanufacturers. However, data on the distribution of these products was not included in the study.

This issue is important, since there was a noticeable variability in the results between the different remanufactured cartridge brands. However, without data on the relative market share of these products, it was determined that using a straight average of all of the data elements was representative of the available pool of remanufactured cartridges on the market. For the brands demonstrating lower performance results, it was not clear if they were more or less representative of the market average. Thus, it was not possible to make a reasonable determination whether to exclude a brand.

While the performance characteristics play an important role in this life cycle study, it was determined that the uncertainty around market share would not have a significant impact on the overall inventory of the remanufactured cartridge model. The goal of the study was to evaluate different remanufactured cartridge choices available to the consumer. While market share was not addressed, QualityLogic tested brands found in the market, and tested using off the shelf conditions.

Data Quality Evaluation

This section presents the study's data quality in accordance with the ISO 14041 standard.

Temporal, Technological, and Geographical Coverage

Temporal

- Current bill of materials
- Generally recognized current practices for remanufacturing
- Data sets: electricity grid is 2002 mix of fuels. Production and combustion data is data are from the 1990s.
- Materials production data on most of the materials are from the 1990's. The plastics production data are from the early 2000s.

Technological data

- Material and fuel production technologies correspond for the most part with the time period around the data collection. It is reasonably certain, though, that most of the material and fuel production methods have not changed drastically over the last 10 to 15 years. In the case of paper production, those technologies have not drastically changed from the time the data set was produced.

Geographical

- Use of European electricity grid and fuel production data.
- Paper production is European.
- Some of the materials data sets are European, and others are US data, based on availability and the choice of the higher quality data if European and US data were both available. When US data were used, an attempt was made to apply European fuel production data to customize the data set to European.

Data Consistency

Consistency looks at how uniformly the study methodology is applied to the various components of the analysis. The HP cartridge and the three remanufacturing scenarios are consistent for all of the life cycle stages in terms of modeling and assumptions.

Data Reproducibility

The data used for this study are in a format in which results can be reproduced.

Data Representativeness

The HP 96A current bill of materials was provided for this study so that specific data may be considered temporally representative. However, the remanufactured cartridges are theoretical market examples, so the level of representativeness is unknown.

Data Precision and Completeness

Precision cannot be measured since only one data set (or one data source) was provided for each HP cartridge, and completeness is not applicable since primary data were not collected.

Section 7

Conclusions

The goal of this study was to compare the environmental performance of HP LaserJet cartridge, with recycling and a representative model of a comparable remanufactured cartridge, and examine the present application of the Reduce-Reuse-Recycle hierarchy to print cartridges. Conventional wisdom has focused on waste management concerns as the driver for product choice – in essence, presuming remanufactured cartridges are better for the environment because they represent recovered (or Reused) material. From a practical perspective, however, cartridges are purchased for a specific function – to print pages of sufficient quality to meet the user's needs. This study was designed to provide a comparative assessment of the HP OEM cartridges versus remanufactured cartridges, with a focus on the full life of the products. The results of this study make it clear that a focus on the function and functional output of the cartridge is relevant and important.

Results from the comparison of life cycle impacts of an HP cartridge recycled at end of life and a remanufactured cartridge do not decidedly favor either cartridge. The results of certain life cycle impact assessment categories for remanufactured cartridges were less than those associated with the HP cartridge, and greater than the HP cartridge in other instances. All but three of the results differ by less than 20 percent; more than half differ by less than 10 percent. Therefore no definitive statement can be made about the environmental preferability of one product type over the other. This lack of differentiation is itself a significant finding, and calls into question the commonly promoted belief that remanufactured cartridges create far less environmental impact than OEM cartridges.

Results from this study challenge the school of thought that remanufactured brands are "better" for the environment because they reuse materials in the development of a new cartridge. The study reveals that although material sourcing impacts are significant, critical drivers of environmental impacts over the life cycle are print quality, cartridge reliability and end-of-life management.

- Print Quality Consistency – This and previous studies have demonstrated that the greatest proportion of environmental impacts occur during the use stage, through the consumption of paper. Uneven print quality that results in unusable pages can increase paper consumption due to reprints, significantly increasing paper consumption and its associated environmental impacts. Conversely, a cartridge that consistently produces high quality output will minimize wasted pages.

- Cartridge Reliability – Lower reliability that results in premature cartridge failures reduces the average page yield of a cartridge. Lower page yields result in an increase in environmental impacts per printed page because production, transport and end-of-life disposition impacts are associated with a smaller number of printed pages. Cartridge reliability, therefore, has potential for a considerable decrease in environmental impacts required to produce usable pages.

- End-of-life Management – The benefits of a recycling program, (e.g., recovery of materials and energy from end-of-life cartridges), were clearly demonstrated as an important aspect of the cartridge life cycle.

It can thus be concluded that a cartridge that reliably prints high quality pages, and in particular one that is recycled at end of life, most likely has lower overall environmental impacts than a cartridge that doesn't share these attributes.

A key lesson to be taken from this study is that systems should be compared on a functional basis, not solely a product basis. With the present application of the waste hierarchy to print cartridges (which emphasizes the end of life of the product), remanufactured cartridges may appear to be environmentally preferable to OEM cartridges because reuse is conventionally placed at a higher importance than recycling. However, this narrow perspective fails to account for the production impacts of remanufacturing and further ignores the additional waste and other environmental impacts that could be generated at other stages of the product life cycle, including resources that are wasted because of inefficient printing. This highlights the need to reconsider conventional thinking about cartridge environmental preference. Environmentally based decision-making regarding cartridges, whether original or remanufactured, should consider the cartridge's entire life, and most importantly, take into account the service it provides: reliable printing performance to produce usable pages.

Section 8

References

1. ISO 14040:1997(E), the International Standard of the International Standardization Organization, Environmental management. Life cycle assessment. Principles and framework.

2. ISO 14041:1998(E), the International Standard of the International Standardization Organization, Environmental management. Life cycle assessment. Goal and scope definition and inventory analysis.

3. ISO 14042:2000(E), the International Standard of the International Standardization Organization, Environmental management. Life cycle assessment. Life cycle impact assessment.

4. Ecobalance, Inc., March 1998. *Final Report on the LCA of a LaserJet Cartridge*. HP Confidential Internal Study. This study compared the 92298A LaserJet Cartridge with the remanufactured version and focused on end-of-life management strategies.

5. Hewlett-Packard, December 2003, Excel file containing Toner Cartridge Parts and Materials List for C4096A.

6. QualityLogic, Inc., November 4, 2003. *Reliability Comparison Study of HP Toner Cartridges vs. Remanufactured Cartridges World Wide SKUs,* plus Excel worksheet “2200 Summary.”

Section 9

Appendices

Appendix 1: HP Cartridge Information

Appendix 2: Characterization Factors for Impact Categories

Appendix 3: Major Internal Components of a Toner Cartridge

Appendix 4: Remanufacturing Operations

Appendix 5: QualityLogic Test Methodology

Appendix 6: QualityLogic Printed Page Samples

Appendix 7: Life Cycle Inventory Results Tables

Appendix 1 :
HP Cartridge Information

Table 11: HP Cartridge Information

SKU (Selectability #)	Relevance	Page Yield[36]	Photo	Remarks
C4096A (No. 96A)	Current LCA QualityLogic Study	5,000 pages		Target market: Consumer and small business
92298A (No. 98A)	1998 LCA	6,800 pages		Target market: Consumer and business

[36] Page yields are based on 5 percent coverage.

Appendix 2:
Characterization Factors for Impact Categories

Global Warming Potential

Table 12: GWP Characterization Factors

Substance	Characterization Factors: Life cycle inventory result is multiplied by the following to obtain g eq. CO_2
Carbon Dioxide (CO_2, fossil)	1
Methane (CH_4)	23
Nitrous Oxide (N_20)	296
Carbon Tetrafluoride (CF4)	5700
Halon 1301 (CF3Br)	6900

Source

Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001).

Acidification Potential

Table 13: Acidification Potential Characterization Factors

Substance	Characterization Factors: Life cycle inventory result is divided by the following to obtain g eq. H+
Ammonia (NH_3)	17
Hydrogen Chloride (HCl)	36.5
Hydrogen Fluoride (HF)	20
Hydrogen Sulfide (H_2S)	17
Nitrogen Oxides (NOx as NO_2)	46
Sulfur Oxides (SOx as SO_2)	32

Source

Centre of Environmental Science (CML), *Environmental life cycle assessment of products*. Guide and Backgrounds. Leiden University, The Netherlands, October 1992.

Eutrophication potential

Table 14: Eutrophication Potential Characterization Factors

Substance	Characterization Factors: Life cycle inventory result is divided by the following to obtain g eq. PO_4
Ammonia (NH_3)	0.35
Nitrogen Oxides (NOx as NO_2)	0.13
Nitrous Oxide (N2O)	0.27
Ammonia (NH_4+, NH_3, as N)	0.35
COD (Chemical Oxygen Demand)	0.022
Nitrate (NO_3-)	0.1
Nitrogenous Matter (unspecified, as N)	0.42
Phosphates (as P)	1.0
Phosphorous Matter (unspecified)	3.06

Source

Centre of Environmental Science (CML). *CML 2 baseline 2000 method*. Leiden University, The Netherlands, 2001.

Resource Depletion Potential

Table 15: Resource Depletion Potential Characterization Factors

Substance	Characterization Factors: Life cycle inventory result is multiplied by the following to obtain MJ surplus
Bauxite ore	0.5
Coal (in ground)	0.252
Copper ore	0.415
Iron ore	0.029
Lignite (in ground)	0.252
Natural Gas (in ground)	4.55
Oil (in ground)	6.1
Zinc ore	0.164

Source

PRé Consultants, Ecoindicator 99 (*2000 update*, update from EcoIndicator 95).. Amersfoort. The Netherlands, 2000.

Photochemical smog potential

Table 16: Photochemical Smog Potential Characterization Factors

Substance	Characterization factors: Life cycle inventory result is multiplied by the following to obtain g eq. ethylene
Aldehyde (unspecified)	0.443
Aromatic Hydrocarbons (unspecified)	0.761
Ethylene (C2H4)	1
Hydrocarbons (except methane)	0.416
Hydrocarbons (unspecified)	0.377
Methane (CH4)	0.007

Source

United Nations - Economic Commission for Europe, *Protocol to the convention on long-range transboundary air pollution concerning the control of emissions of volatile organic compounds of the transboundary fluxes*, Geneva, 1991.

Human toxicity potential

Table 17: Human Toxicity Potential Characterization Factors

Substance	Characterization factors: Life cycle inventory result is multiplied by the following to obtain DALYs
Acetaldehyde (CH3CHO) - air	2.16E-10
Arsenic (As) - air	2.46E-05
Benzene (C6H6) - air	2.5E-09
Benzo(a)anthracene - air	5.86E-05
Benzo(a)pyrene (C20H12) - air	3.98E-06
Cadmium (Cd) - air	0.000135
Dibenzo(a,h)anthracene - air	0.031
Formaldehyde (CH2O) - air	9.91E-10
Metals (unspecified) - air	5.2E-06
Nickel (Ni) - air	2.35E-05
Polycyclic Aromatic Hydrocarbons (PAH, unspecified) - air	1.7E-07
Arsenic (As3+, As5+) - water	6.57E-05
Benzene (C6H6) - water	4.12E-09
Cadmium (Cd++) - water	7.12E-05

Substance (cont.)	Characterization factors: Life cycle inventory result is multiplied by the following to obtain DALYs (cont.)
Chromium (Cr VI) - water	0.000343
Formaldehyde (CH2O) - water	4.97E-09
Nickel (Ni++, Ni3+) - water	3.11E-05
Polycyclic Aromatic Hydrocarbons (PAH, unspecified) - water	2.6E-06
Tetrachloroethylene (C2Cl4) - water	4.72E-10

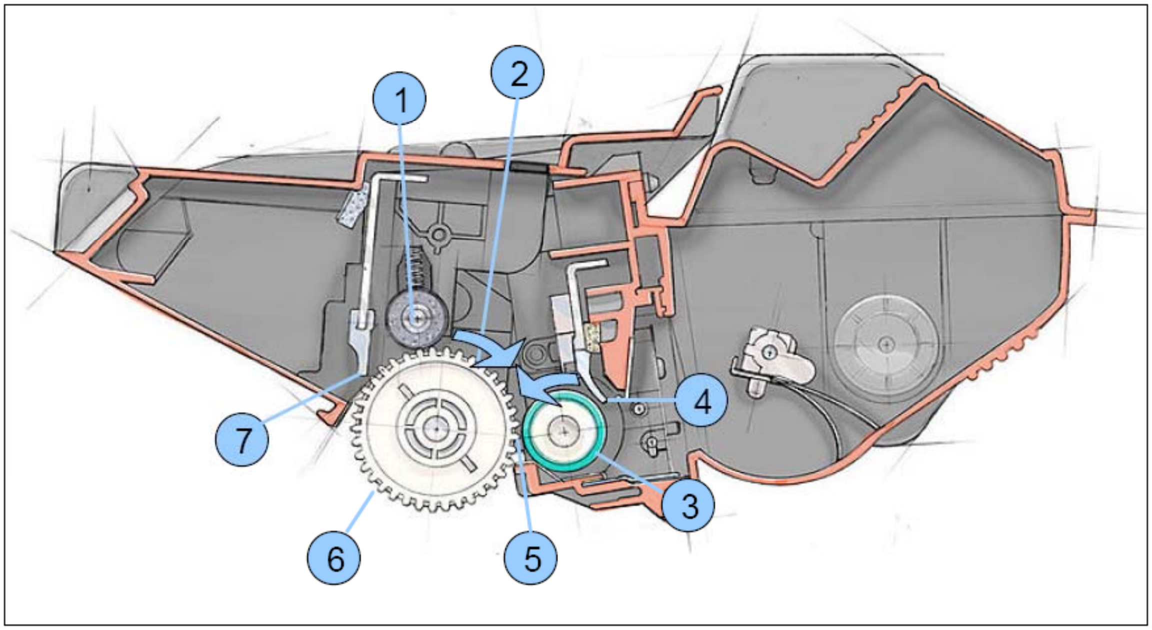
Source

Ecoindicator 99 (*2000 update*, update from EcoIndicator 95) Carcinogenic effects. PRé Consultants. Amersfoort, The Netherlands, 2000.

Appendix 3 :
Major Internal Components of a LaserJet Cartridge

The figure below presents a cross-section of an HP 96A LaserJet cartridge, identifying each of the major internal components.

Figure 16: Major Internal Components of a LaserJet Cartridge



1. The primary charge roller (PCR) places a uniform negative charge on the surface of the organic photo-conducting (OPC) drum.

2. The laser passes through an aperture on top of the cartridge striking the OPC drum, which creates a temporary positive charge.

3. The developer roller circles through the toner hopper. Since the developer roller is magnetic, toner adheres to the surface of the roller.

4. The doctor blade smoothes the toner on the developer roller to a fine, consistent layer.

5. The developer roller and the OPC roll together but do not touch. Toner on the developer roller is attracted to the positively charged spots on the OPC and 'jumps' across the narrow gap to fill in these spots. Unused toner on the developer roller rotates around again into the toner hopper.

6. The OPC Drum rotates around to meet the paper, transferring the toner to the page. The paper then continues on to the fuser.

7. The wiper blade removes any excess toner and media debris from the drum, cleaning it for the next cycle.

Appendix 4 :
The Cartridge Remanufacturing Process

Overview of a Remanufactured Cartridge

A remanufactured toner printer cartridge is typically considered to be a cartridge in which, at a minimum, the plastic body, the gears, and the non-image producing components inside the cartridge have been taken from a previously used and empty cartridge.

In order to remanufacture the cartridge, the toner must be refilled and perhaps some components must be replaced. Different remanufacturers will replace or reuse the imaging components [toner, organic photoconducting (OPC) drum, charge roller, developer roller, doctor blade and wiper blade] as they see fit. Some remanufacturers reuse every component they can, while others have a policy of replacing most. Each will have an individual production strategy to minimize cost while producing an acceptable level of quality. That said, it appears that no remanufacturer replaces all the imaging components all the time.

The Cartridge Remanufacturing Process

The first step in any remanufacturing process is obtaining the empty cartridge, commonly known in the industry as a "core." Industry data strongly suggest that of the cores that are remanufactured, most are remanufactured only a single time, or a single "cycle." According to the remanufacturer trade publication, "[In] 2000, at least 70 percent of first remanufacturing cycle cores were abandoned." Use of so-called "first-cycle" or "virgin" cores, cartridges that have not previously been remanufactured, can represent the optimum quality/reliability/cost strategy for remanufacturers.

Next, the remanufacturer must disassemble the cartridge. Disassembling a HP 96A is a multi-step process that requires the removal of sensitive components such as the OPC drum. The disassembly of precision-aligned components can fundamentally alter the cartridge. As a result, a disassembled cartridge does not reassemble as smoothly as it did in original assembly, and remanufacturers must resort to clips, glues and sealants not found in or associated with an OEM cartridge. After completing the desired degree of disassembly, components can be checked to determine their suitability for reuse. It is difficult to predict component performance in a second (and additional) cycle. This is such a critical aspect of remanufacturing that the remanufacturing industry is beginning to fund research centers (such as the National Center for Remanufacturing and Resource Recovery, or NCR3) to develop scientific methods for determining the status of reclaimed components. This research is still at a very early stage of development and most remanufacturers are not employing these techniques in their remanufacturing processes.

Replacing the internal components is also technically challenging. The laser printing process is highly dependent upon the consistent and known interaction of the imaging components. Because remanufacturers use a variety of alternating suppliers to provide imaging components (including some reused components as discussed above), the interaction of these components from cartridge to cartridge is different.

For example, the OPC drum may be from Fuji, Mitsubishi or TSIC; the toner from Densigraphix, Oasis or Color Image; the developer roller from OTC, Static Control or Graphic Technologies; and doctor and wiper blades from Kuroki, Future Graphics or Tuico. Of course, these suppliers do not ensure that their components interact consistently with those from other suppliers. Rather, it is up to the individual remanufacturer to determine which combination of OPC, toner and developer roller produces the most satisfactory results.

The reassembly stage presents further challenges. Components must be replaced with a high degree of precision. Any degree of error – a charge roller pressing too hard on the OPC, a wiper blade set askew to the drum, a seal not completely sealed – is likely to affect cartridge performance. Sometimes the consequences are inconsequential, sometimes they are significant.

Another significant aspect of cartridge remanufacture is lubricant use. Remanufacturers, when compared to OEMs, use comparatively large amounts of lubricants in reassembly. While lubricants reduce the amount of friction between the imaging components, they also tend to ”break free” during the life of the cartridge and migrate through the imaging system. This is a frequent cause of intermittent print quality defects (amoeba-like spots in random locations) that appear, move around, and then disappear throughout the life of the cartridge.

Appendix 5:
QualityLogic Test Methods and Materials

The following excerpts come from the QualityLogic LaserJet Study pages 2-7 (Reference 5).

Procurement

- QualityLogic procured all printers, toner cartridges, and paper for the test from standard retail channels where possible. One brand was not available through a local retail channel and was procured through retail by a European agent arranged by Hewlett-Packard.

- Every effort was made to obtain cartridges from various vendors in order to cover a variety of manufacturing dates. Some cartridges were only available from a single source. Cartridge markings were reviewed and support significant lot variation. Cartridges were also ordered through various shipping means.

- Cartridge models selected for testing represent the cartridges for which there is the largest installed base and thus the largest aftermarket. Another selection requirement was that the cartridge be supported by the availability of new printers for testing.

Brand Selection

Remanufactured brands were selected to represent the top tier of remanufactured brands worldwide. The brands were selected because they seem to have the largest overall market share when the worldwide market is considered and offered the key aftermarket cartridges.

Sample Sizes

A total of 30 of each remanufacturer's toner cartridges – a total of 180 remanufactured toner cartridges – and 50 HP LaserJet toner cartridges were tested. Sample sizes were selected with the assistance of HP statisticians based on estimated differences in reliability problem rates.

The Test Printing Process

The sample for each brand of toner cartridge was tested on four new printers to assure the uniformity and accuracy of the test data independent of a particular printer. Each set of four printers was dedicated to the testing of one brand—eliminating any possibility of the impact of one brand on a set of printers affecting the results for another cartridge brand. Yields of usable and unusable pages were recorded for all printers and analyzed to verify that there were no issues with yield/reliability differences between printers.

- Printer and driver settings were left at factory default settings.

- HP original cartridges shipped with the printer were exhausted before installing test cartridges.

- The initial condition of each toner cartridge was inspected, as well as ease of installation, compatibility with the printer and end-of-life condition.

- All test pages were serialized and identified by printer to provide exact page counts.

- Printers were not turned off at the end of each day, but instead were allowed to enter "sleep mode" until revived for use the following day. While printing, the printers paused while paper was being loaded into their respective trays. The printer also was paused for up to an hour (average about 45 minutes) while an expended cartridge was removed and a new cartridge prepared and inserted into the printer for use. There were no printer failures during the test.

- Any instructions provided by the cartridge manufacturer for installation and agitation were implemented. In the absence of any such instructions, test personnel followed the instructions provided in the printer's user guide.

- All cartridges instructions directed the user to "gently rock and shake" the cartridge before installation and some to agitate later to extend cartridge life.
- The operator agitated the toner cartridge, at both the first and second detections of a two level reduction in output print quality. Following the second agitation, the toner cartridge was allowed to run to end of life.

- The impact of the toner cartridge on the printer's functionality was also recorded in the areas of consistent operation, leakage of toner inside the printer, and failure of printer components (fusers, image drums, etc).

- Printer operating instructions for maintenance were followed. The cartridge bays were inspected and wiped clean of any residual toner particles and/or paper dust before each new cartridge was installed. Toner cartridges were not installed if they leaked more than a minimal amount of toner when the pull strip was removed.

- The occasional paper jams, skews, and partial prints were logged as printer incidents and entered into the test records but were not included in any calculations regarding cartridge performance or print defects. Skewed and partial pages were not counted in total yield, judged for print quality problems, or counted as defects.

Environmental Conditions

Normal office conditions, temperature (75° ±8°) and relative humidity (40 percent ±20 percent), were maintained for the duration of the test. All cartridges, printers and paper were stabilized in these temperature and humidity conditions for a minimum of 24 hours prior to use and were subject to the same fluctuations.

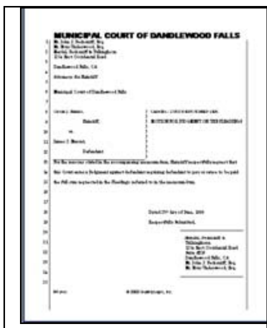
Paper

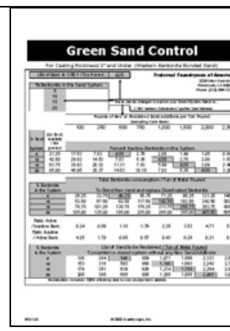
Standard 8 ½ x 11-office papers (20 lb, 84-87 brightness) from HP, Hammermill, Office Depot, Xerox, and Great White were used in sequential order.

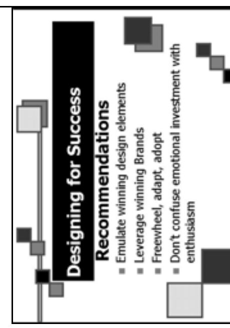
Test Pages

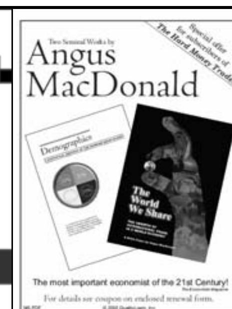
Five test pages (files M1, M2, M3, M4, and M5) were designed using popular application packages to achieve a balanced representation of normal use printing. The applications used and coverage targets are as follows:

- All images were B&W as QualityLogic used a monochrome cartridge
- Each of the test files was printed on 11 printers and scanned to determine the average page coverage. The Adobe PhotoShop, Version 5.05 histogram option was used to count the number of pixels in a bitmap image.
- The test pages were sent to each printer in sequential order (i.e. M1, M2, M3, M4, M5, M1, M2). Print quality assessments of the pages printed by each toner cartridge and printer combination were compared at regular intervals throughout the life of the cartridges in the test.









File: M1 **Application:** Microsoft Word XP **Description:** Word Document **Coverage:** 5 percent	**File:** M2 **Application:** Microsoft Internet Explorer 6.0 **Description:** Web Browser Page **Coverage:** 9 percent	**File:** M3 **Application:** Microsoft Excel XP **Description:** Excel Worksheet **Coverage:** 15 percent	**File:** M4 **Application:** Microsoft PowerPoint XP **Description:** PowerPoint slide **Coverage:** 20 percent	**File:** M5 **Application:** Adobe Acrobat Distiller 5.0 **Description:** PDF v1.14 file (built from a Corel Draw 8.0 rendering.) **Coverage:** 22 percent

End of Life Criteria

End of life was declared when the toner cartridge had ceased to print acceptable pages due to an ongoing malfunction or when its pure text page (M1) displayed a 3mm area from side to side (in the direction of the paper motion), that contained no toner. This measurement of end of life is per an ISO standard draft that was in review at the time this test project was designed in mid-2002.

Print Quality

Four aspects of print quality: legibility, resolution, definition, and uniformity, were observed for all pages printed. The initial and end of life pages as well as 5 of every 100 pages throughout the operational life of the toner cartridge were retained as well as all pages with observed print quality defects.

- A Level 5 page has no apparent artifacts with the identifying rule of thumb being that a user would put this page in his or her resume. Combined with Level 4, these are defined as “Usable” pages.
- A Level 4 page may have a minor flaw such as a speck or uneven graphic rendering but the average user would still use it in a typical business document. Combined with Level 5, these pages are defined as “Usable”.
- A Level 3 page is sufficiently flawed that it would not be circulated to others as a business document and would only be acceptable as a draft page. We defined these pages as “Unusable”.
- Level 2 pages have lost some legibility. We defined these pages as “Unusable” pages.
- Level 1 pages have lost content. We defined these pages as “Unusable” pages.

Appendix 6:
QualityLogic Printed Page Samples

The following pages present the printing quality levels 5 through 1 as defined by QualityLogic. The page scans were made of pages printed with a cartridge similar to the subject of this study.

Figure 17: Level 5 Page

Figure 18: Level 4 Page

Figure 19: Level 3 Page

Figure 20: Level 2 Page

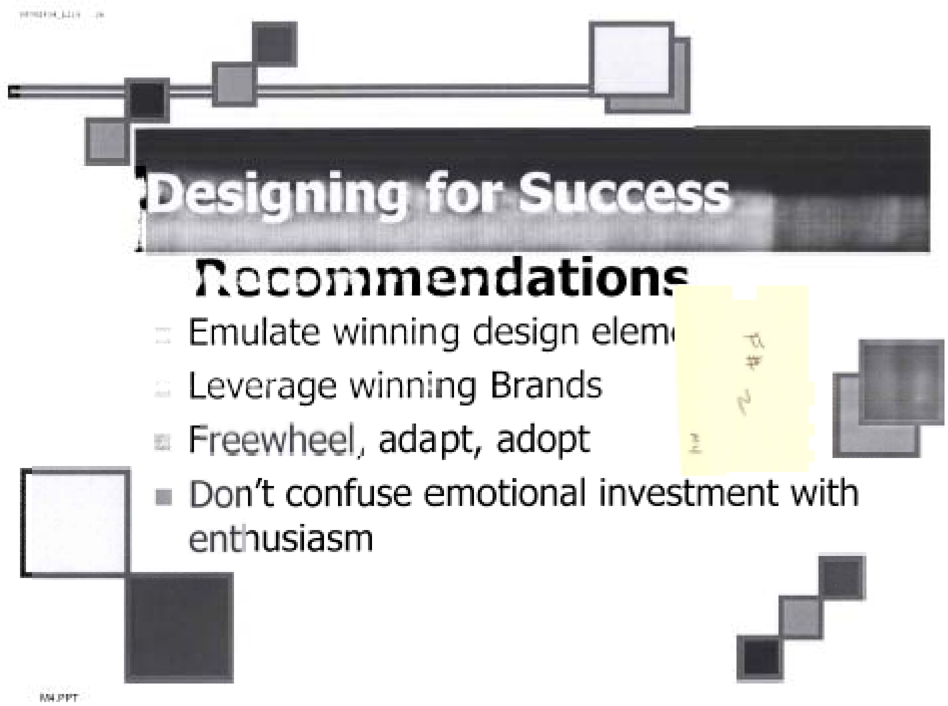


Figure 21: Level 1 Page

Appendix 7 :
Life Cycle Inventory Results Tables

Life cycle inventory and life cycle impact assessment results are presented in the following tables. Table 18 presents the overall life cycle comparison of the 96A cartridges, while Table 19 and Table 20 provide the contribution of each life cycle stage of the HP 96A and the R 96A, respectively.

Table 18: Life Cycle Inventory and Life Cycle Impact Assessment Results:
HP 96A vs. R 96A per 100 Usable Pages (North America)

			HP 96A Baseline	Reman 96A Baseline
Inputs from Nature	Barium Sulfate (BaSO4, in ground)	kg	6.4 E-7	1.5 E-7
	Bauxite (Al2O3, ore)	kg	2.2 E-2	1.0 E-3
	Bentonite (Al2O3.4SiO2.H2O, in ground)	kg	2.1 E-7	8.3 E-8
	Calcium Sulfate (CaSO4, ore)	kg	2.1 E-8	8.2 E-9
	Clay (in ground)	kg	6.5 E-2	6.8 E-2
	Coal (in ground)	kg	4.7 E-2	4.4 E-2
	Copper (Cu, ore)	kg	0.0 E+0	0.0 E+0
	Gravel (unspecified)	kg	8.8 E-9	1.4 E-9
	Iron (Fe, ore)	kg	-8.5 E-4	4.9 E-3
	Lignite (in ground)	kg	1.4 E-2	1.5 E-2
	Limestone (CaCO3, in ground)	kg	2.2 E-2	1.7 E-2
	Natural Gas (in ground)	kg	9.5 E-2	8.7 E-2
	Oil (in ground)	kg	8.3 E-2	6.8 E-2
	Sand (in ground)	kg	1.3 E-3	1.3 E-3
	Sodium Chloride (NaCl, in ground or in sea)	kg	7.1 E-2	6.8 E-2
	Uranium (U, ore)	kg	1.1 E-5	8.9 E-6
	Zinc (Zn, ore)	kg	1.7 E-9	1.0 E-10
	Water Used (total)	liter	3.7 E+1	3.9 E+1
Air	Acenaphthene (C12H10)	g	5.3 E-9	3.3 E-10
	Acenaphthylene (C12H8)	g	5.6 E-10	1.2 E-10
	Acetaldehyde (CH3CHO)	g	8.1 E-7	1.5 E-7
	Acetic Acid (CH3COOH)	g	0.0 E+0	0.0 E+0
	Acetone (CH3COCH3)	g	0.0 E+0	0.0 E+0
	Acetylene (C2H2)	g	0.0 E+0	0.0 E+0
	Aldehyde (unspecified)	g	1.8 E-1	1.9 E-1
	Alkane (unspecified)	g	0.0 E+0	0.0 E+0
	Alkene (unspecified)	g	0.0 E+0	0.0 E+0
	Alkyne (unspecified)	g	0.0 E+0	0.0 E+0
	Aluminum (Al)	g	1.1 E-6	6.3 E-7
	Ammonia (NH3)	g	2.3 E-2	2.4 E-2
	Anthracene (C14H10)	g	7.6 E-10	1.4 E-10
	Antimony (Sb)	g	1.4 E-6	2.3 E-7
	AOX (Adsorbable Organic Halogens)	g	0.0 E+0	0.0 E+0
	Aromatic Hydrocarbons (unspecified)	g	4.3 E-3	4.6 E-3
	Arsenic (As)	g	1.2 E-5	6.1 E-6
	Barium (Ba)	g	7.4 E-7	1.4 E-7

Table 18 (cont.)

			HP 96A Baseline	Reman 96A Baseline
Air (cont.)	Benzaldehyde (C6H5CHO)	g	0.0 E+0	0.0 E+0
	Benzene (C6H6)	g	4.5 E-3	2.6 E-3
	Benzo(a)anthracene	g	1.1 E-9	1.0 E-10
	Benzo(a)pyrene (C20H12)	g	2.2 E-5	5.7 E-7
	Benzo(b)fluoranthene	g	3.1 E-10	5.9 E-11
	Benzo(ghi)perylene	g	3.8 E-10	5.1 E-11
	Benzo(k)fluoranthene	g	3.1 E-10	5.9 E-11
	Berylium (Be)	g	0.0 E+0	0.0 E+0
	Boron (B)	g	0.0 E+0	0.0 E+0
	Bromium (Br)	g	0.0 E+0	0.0 E+0
	Butane (C4H10)	g	1.8 E-4	6.3 E-5
	Butane (n-C4H10)	g	0.0 E+0	0.0 E+0
	Butene (1-CH3CH2CHCH2)	g	0.0 E+0	0.0 E+0
	Cadmium (Cd)	g	1.9 E-5	2.0 E-5
	Calcium (Ca)	g	9.7 E-7	5.4 E-7
	Carbon Dioxide (CO2, biomass)	g	8.9 E+2	9.3 E+2
	Carbon Dioxide (CO2, fossil)	g	5.3 E+2	4.9 E+2
	Carbon Disulfide (CS2)	g	5.2 E-7	4.3 E-8
	Carbon Monoxide (CO)	g	6.0 E-1	6.3 E-1
	Carbon Tetrafluoride (CF4)	g	9.3 E-4	2.2 E-5
	Chlorides (Cl-)	g	8.6 E-5	1.1 E-5
	Chlorinated Matter (unspecified, as Cl)	g	3.2 E-5	3.6 E-6
	Chlorine (Cl2)	g	1.1 E-4	6.8 E-5
	Chrysene (C18H12)	g	5.5 E-10	8.9 E-11
	Cobalt (Co)	g	2.3 E-6	5.9 E-7
	Copper (Cu)	g	-9.0 E-7	1.2 E-7
	Cyanide (CN-)	g	3.6 E-6	6.8 E-7
	Dibenzo(a,h)anthracene	g	2.8 E-10	4.2 E-11
	Dichlorobenzene (1,4-C6H4Cl2)	g	1.0 E-7	3.6 E-8
	Dimethyl Benzanthracene (7,12-C20H16)	g	1.3 E-9	4.7 E-10
	Dioxins (unspecified)	g	3.4 E-10	1.4 E-10
	Ethane (C2H6)	g	2.7 E-4	9.3 E-5
	Ethanol (C2H5OH)	g	0.0 E+0	0.0 E+0
	Ethylbenzene (C8H10)	g	0.0 E+0	0.0 E+0
	Ethylene (C2H4)	g	0.0 E+0	0.0 E+0
	Fluoranthene	g	1.8 E-9	3.0 E-10
	Fluorene (C13H10)	g	2.0 E-9	3.5 E-10

Table 18 (cont.)

			HP 96A Baseline	Reman 96A Baseline
Air (cont.)	Fluorides (F-)	g	4.5 E-3	1.1 E-4
	Fluorine (F2)	g	3.4 E-7	8.0 E-9
	Formaldehyde (CH2O)	g	9.0 E-5	4.4 E-5
	Halogenated Hydrocarbons (unspecified)	g	5.1 E-6	7.0 E-7
	Halogenated Matter (unspecified)	g	1.7 E-6	1.5 E-6
	Halon 1301 (CF3Br)	g	9.0 E-6	9.7 E-6
	Heptane (C7H16)	g	0.0 E+0	0.0 E+0
	Hexane (C6H14)	g	1.6 E-4	5.4 E-5
	Hydrocarbons (except methane)	g	6.6 E-1	6.7 E-1
	Hydrocarbons (unspecified)	g	3.5 E-1	8.5 E-2
	Hydrogen (H2)	g	1.2 E-2	1.0 E-3
	Hydrogen Chloride (HCl)	g	3.3 E-2	2.5 E-2
	Hydrogen Cyanide (HCN)	g	2.4 E-5	2.7 E-5
	Hydrogen Fluoride (HF)	g	2.8 E-3	2.5 E-3
	Hydrogen Sulfide (H2S)	g	1.4 E-2	1.4 E-2
	Indeno (1,2,3,c,d) Pyrene	g	4.7 E-10	7.8 E-11
	Iodine (I)	g	0.0 E+0	0.0 E+0
	Iron (Fe)	g	2.2 E-6	1.2 E-6
	Isophorone	g	8.3 E-7	1.6 E-7
	lanthanum (La)	g	0.0 E+0	0.0 E+0
	Lead (Pb)	g	5.8 E-5	7.3 E-5
	Magnesium (Mg)	g	7.6 E-5	4.0 E-5
	Manganese (Mn)	g	2.7 E-5	2.4 E-5
	Mercaptans	g	3.8 E-3	4.0 E-3
	Mercury (Hg)	g	1.1 E-5	1.0 E-5
	Metals (unspecified)	g	6.9 E-3	7.4 E-3
	Methane (CH4)	g	1.1 E+0	1.1 E+0
	Methanol (CH3OH)	g	0.0 E+0	0.0 E+0
	Methyl Cholanthrene (3-C21H16)	g	1.6 E-10	5.4 E-11
	Methyl Naphthalene (2-C11H10)	g	2.1 E-9	7.2 E-10
	Molybdenum (Mo)	g	3.8 E-7	1.1 E-7
	Naphthalene (C10H8)	g	3.5 E-7	5.6 E-8
	Nickel (Ni)	g	4.9 E-4	5.1 E-4
	Nitrogen Oxides (NOx as NO2)	g	3.1 E+0	2.8 E+0
	Nitrous Oxide (N2O)	g	1.7 E-2	1.4 E-2
	Organic Matter (unspecified)	g	3.4 E-2	1.8 E-2
	Particulates (PM 10)	g	1.3 E-5	7.2 E-6

Table 18 (cont.)

			HP 96A Baseline	Reman 96A Baseline
Air (cont.)	Particulates (unspecified)	g	1.7 E+0	1.1 E+0
	Pentane (C_5H_{12})	g	2.2 E-4	7.8 E-5
	Phenanthrene ($C_{14}H_{10}$)	g	6.4 E-9	1.3 E-9
	Phenol (C_6H_5OH)	g	2.3 E-8	4.3 E-9
	Phosphorus (P)	g	3.0 E-6	6.5 E-7
	Phosphorus Pentoxide (P_2O_5)	g	0.0 E+0	0.0 E+0
	Polycyclic Aromatic Hydrocarbons	g	6.9 E-4	8.0 E-5
	Potassium (K)	g	0.0 E+0	0.0 E+0
	Propane (C_3H_8)	g	4.7 E-5	3.0 E-5
	Propionic Acid (CH_3CH_2COOH)	g	0.0 E+0	0.0 E+0
	Propylene (CH_2CHCH_3)	g	0.0 E+0	0.0 E+0
	Pyrene ($C_{16}H_{10}$)	g	1.3 E-9	2.5 E-10
	Scandium (Sc)	g	0.0 E+0	0.0 E+0
	Selenium (Se)	g	2.1 E-6	4.0 E-7
	Silicon (Si)	g	9.7 E-7	5.4 E-7
	Sodium (Na)	g	5.8 E-6	3.2 E-6
	Strontium (Sr)	g	0.0 E+0	0.0 E+0
	Sulfur Oxides (SO_x as SO_2)	g	2.7 E+0	2.5 E+0
	Sulfuric Acid (H_2SO_4)	g	1.6 E-5	1.3 E-6
	Tars (unspecified)	g	0.0 E+0	0.0 E+0
	Thallium (Tl)	g	0.0 E+0	0.0 E+0
	Thorium (Th)	g	0.0 E+0	0.0 E+0
	Tin (Sn)	g	0.0 E+0	0.0 E+0
	Titanium (Ti)	g	0.0 E+0	0.0 E+0
	Toluene ($C_6H_5CH_3$)	g	2.4 E-6	4.5 E-7
	Uranium (U)	g	0.0 E+0	0.0 E+0
	Vanadium (V)	g	2.3 E-5	9.4 E-6
	Volatile Organic Carbon (VOC)	g	6.2 E-2	7.0 E-2
	Xylene ($C_6H_4(CH_3)_2$)	g	4.4 E-7	1.9 E-7
	Zinc (Zn)	g	2.0 E-3	1.6 E-3
	Zirconium (Zr)	g	0.0 E+0	0.0 E+0
Water	Acids (H^+)	g	9.7 E-4	9.8 E-4
	Aldehyde (unspecified)	g	0.0 E+0	0.0 E+0
	Alkane (unspecified)	g	0.0 E+0	0.0 E+0
	Alkene (unspecified)	g	0.0 E+0	0.0 E+0
	Aluminum (Al^{3+})	g	3.9 E-2	5.2 E-2
	Ammonia (NH_4^+, NH_3, as N)	g	9.2 E-3	9.5 E-3

Water (cont.)	AOX (Adsorbable Organic Halogens)	g	1.8 E-1	1.9 E-1
	Aromatic Hydrocarbons (unspecified)	g	1.8 E-3	1.9 E-3
	Arsenic (As3+, As5+)	g	7.6 E-5	1.0 E-4
	Barium (Ba++)	g	7.6 E-3	9.0 E-3
	Barytes	g	0.0 E+0	0.0 E+0
	Benzene (C6H6)	g	0.0 E+0	0.0 E+0
	BOD5 (Biochemical Oxygen Demand)	g	3.3 E+0	3.5 E+0
	Boron (B III)	g	0.0 E+0	0.0 E+0
	Cadmium (Cd++)	g	4.6 E-6	5.4 E-6
	Calcium (Ca++)	g	8.3 E-2	9.9 E-3
	Carbonates (CO3--, HCO3-, CO2, as C)	g	3.2 E-4	4.9 E-5
	Cerium (Ce++)	g	0.0 E+0	0.0 E+0
	Cesium (Cs++)	g	0.0 E+0	0.0 E+0
	Chlorates (ClO3-)	g	5.9 E-1	6.2 E-1
	Chlorides (Cl-)	g	5.5 E+0	4.4 E+0
	Chlorinated Matter (unspecified, as Cl)	g	2.9 E-6	3.1 E-6
	Chlorine (Cl2)	g	2.1 E-5	2.4 E-6
	Chloroform (CHCl3)	g	0.0 E+0	0.0 E+0
	Chromate (CrO4--)	g	3.4 E-7	8.0 E-9
	Chromium (Cr III)	g	0.0 E+0	0.0 E+0
	Chromium (Cr III, Cr VI)	g	3.7 E-4	5.3 E-4
	Chromium (Cr VI)	g	7.6 E-5	7.8 E-5
	Cobalt (Co I, Co II, Co III)	g	0.0 E+0	0.0 E+0
	COD (Chemical Oxygen Demand)	g	1.5 E+1	1.6 E+1
	Copper (Cu+, Cu++)	g	1.9 E-4	2.5 E-4
	Cyanide (CN-)	g	8.3 E-6	8.6 E-6
	Dissolved Matter (unspecified)	g	5.3 E-2	1.5 E-2
	Dissolved Organic Carbon (DOC)	g	1.3 E-3	1.3 E-3
	Ethylbenzene (C6H5C2H5)	g	0.0 E+0	0.0 E+0
	Fluorides (F-)	g	8.8 E-4	4.4 E-5
	Formaldehyde (CH2O)	g	0.0 E+0	0.0 E+0
	Halogenated Matter (organic)	g	4.7 E-12	3.1 E-12
	Hexachloroethane (C2Cl6)	g	0.0 E+0	0.0 E+0
	Hydrocarbons	g	2.2 E-4	0.0 E+0
	Hydrocarbons (unspecified)	g	1.8 E-3	1.3 E-3
	Hypochlorite (ClO-)	g	0.0 E+0	0.0 E+0
	Hypochlorous Acid (HClO)	g	0.0 E+0	0.0 E+0
	Inorganic Dissolved Matter (unspecified)	g	2.2 E-5	0.0 E+0
	Iode (I-)	g	0.0 E+0	0.0 E+0
	Iron (Fe++, Fe3+)	g	3.2 E-2	3.8 E-2

Water (cont.)	Lead (Pb++, Pb4+)	g	3.2 E-4	4.0 E-4
	Magnesium (Mg++)	g	1.6 E-4	3.2 E-5
	Manganese (Mn II, Mn IV, Mn VII)	g	0.0 E+0	0.0 E+0
	Mercury (Hg+, Hg++)	g	9.4 E-6	1.8 E-6
	Metals (unspecified)	g	2.3 E-2	2.3 E-2
	Methylene Chloride (CH2Cl2)	g	0.0 E+0	0.0 E+0
	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	g	6.6 E-7	7.5 E-7
	Nickel (Ni++, Ni3+)	g	2.0 E-4	2.6 E-4
	Nitrate (NO3-)	g	2.1 E-1	2.2 E-1
	Nitrates (NO3-)	g	4.7 E-9	0.0 E+0
	Nitrites (NO2-)	g	0.0 E+0	0.0 E+0
	Nitrogenous Matter (Kjeldahl, as N)	g	0.0 E+0	0.0 E+0
	Nitrogenous Matter (unspecified, as N)	g	9.7 E-2	1.0 E-1
	Oils (unspecified)	g	5.9 E-2	6.0 E-2
	Organic Dissolved Matter (chlorinated)	g	4.5 E-5	1.5 E-6
	Organic Dissolved Matter (unspecified)	g	3.5 E-3	3.9 E-3
	Organic Matter (unspecified)	g	3.5 E-4	3.8 E-5
	Phenol (C6H5OH)	g	4.7 E-4	4.5 E-4
	Phosphates (PO4 3-, HPO4--, H2PO4-, H3PO4, as P)	g	2.2 E-3	2.2 E-3
	Phosphorous Matter (unspecified, as P)	g	1.7 E-2	1.8 E-2
	Phosphorus (P)	g	0.0 E+0	0.0 E+0
	Phosphorus Pentoxide (P2O5)	g	0.0 E+0	0.0 E+0
	Polycyclic Aromatic Hydrocarbons	g	4.0 E-5	2.7 E-5
	Potassium (K+)	g	6.0 E-4	2.0 E-5
	Rubidium (Rb+)	g	0.0 E+0	0.0 E+0
	Salts (unspecified)	g	3.7 E+0	3.9 E+0
	Saponifiable Oils and Fats	g	0.0 E+0	0.0 E+0
	Selenium (Se II, Se IV, Se VI)	g	0.0 E+0	0.0 E+0
	Silicon Dioxide (SiO2)	g	0.0 E+0	0.0 E+0
	Silver (Ag+)	g	0.0 E+0	0.0 E+0
	Sodium (Na+)	g	9.9 E-1	3.0 E-1
	Strontium (Sr II)	g	0.0 E+0	0.0 E+0
	Sulfate (SO4--)	g	2.0 E+0	2.1 E+0
	Sulfide (S--)	g	6.6 E-5	7.1 E-5
	Sulphites (SO3--)	g	0.0 E+0	0.0 E+0
	Sulphurated Matter (unspecified, as S)	g	0.0 E+0	0.0 E+0
	Suspended Matter (unspecified)	g	1.7 E+0	1.7 E+0
	Tars (unspecified)	g	0.0 E+0	0.0 E+0
	Tetrachloroethylene (C2Cl4)	g	0.0 E+0	0.0 E+0
	Tin (Sn++, Sn4+)	g	0.0 E+0	0.0 E+0

Table 18 (cont.)

			HP 96A Baseline	Reman 96A Baseline
Water (cont.)	Titanium (Ti3+, Ti4+)	g	0.0 E+0	0.0 E+0
	TOC (Total Organic Carbon)	g	5.1 E-1	5.4 E-1
	Toluene (C6H5CH3)	g	2.4 E-4	2.5 E-4
	Tri n-butyl-phosphate (TBP, (C4H9O)3PO)	g	0.0 E+0	0.0 E+0
	Trichlorethane (1,1,1-CH3CCl3)	g	0.0 E+0	0.0 E+0
	Trichloroethylene (C2HCl3)	g	0.0 E+0	0.0 E+0
	Triethylene Glycol (C6H14O4)	g	0.0 E+0	0.0 E+0
	Vanadium (V3+, V5+)	g	0.0 E+0	0.0 E+0
	VOC (Volatile Organic Compounds)	g	0.0 E+0	0.0 E+0
	Xylene (C6H4(CH3)2)	g	0.0 E+0	0.0 E+0
	Zinc (Zn++)	g	4.4 E-4	5.3 E-4
Waste	Waste: hazardous	kg	1.0 E-3	2.7 E-5
	Waste: incineration	kg	0.0 E+0	0.0 E+0
	Waste: municipal and industrial	kg	2.4 E-2	2.1 E-2
	Waste: total	kg	8.9 E-2	1.2 E-1
	Waste: unspecified	kg	7.2 E-3	3.9 E-3
	.Waste: unspecified, to incineration	kg	2.9 E-5	2.3 E-5
	Waste: in Landfills	kg	0.0 E+0	3.9 E-2
	Waste: Bauxite Residues (red mud)	kg	4.8 E-7	3.2 E-7
	Waste: FGD Sludge	kg	4.5 E-4	2.8 E-4
	Waste: Mineral (inert)	kg	4.8 E-2	4.9 E-2
	Waste: Non Mineral (inert)	kg	4.0 E-9	8.9 E-11
	Waste: Non Toxic Chemicals (unspecified)	kg	2.1 E-4	3.0 E-5
	Waste: Slags and Ash (unspecified)	kg	8.0 E-3	3.9 E-3
Energy	Feedstock Energy	MJ	8.9 E+0	8.8 E+0
	Fuel Energy	MJ	2.1 E+1	2.1 E+1
	Non Renewable Energy	MJ	9.9 E+0	8.4 E+0
	Renewable Energy	MJ	2.0 E+1	2.1 E+1
	Total Primary Energy	MJ	3.0 E+1	2.9 E+1
Impacts	Acidification potential	g eq. H+	1.5 E-1	1.4 E-1
	Eutrophication potential	g. eq. PO4	8.8 E-1	8.5 E-1
	Resource depletion potential	MJ surplus	9.7 E-1	8.2 E-1
	Global warming potential	g eq. CO2	5.7 E+2	5.2 E+2
	Photochemical smog potential	g eq. ethylene	5.0 E-1	4.1 E-1
	Human toxicity potential	DALYs	8.9 E-8	9.5 E-8

Table 19: Life Cycle Stage Contribution Life Cycle Inventory and Life Cycle Impact Assessment Results: HP 96A per 100 Usable Pages (North America)

			HP Total LC	Production	Distribution	Use	EOL
Inputs from Nature	Barium Sulfate (BaSO4, in ground)	kg	**6.4 E-7**	8.1 E-7	0.0 E+0	0.0 E+0	-1.7 E-7
	Bauxite (Al2O3, ore)	kg	**2.2 E-2**	3.6 E-2	7.4 E-7	4.3 E-4	-1.4 E-2
	Bentonite (Al2O3.4SiO2.H2O)	kg	**2.1 E-7**	2.1 E-7	0.0 E+0	0.0 E+0	0.0 E+0
	Calcium Sulfate (CaSO4, ore)	kg	**2.1 E-8**	2.1 E-8	0.0 E+0	0.0 E+0	0.0 E+0
	Clay (in ground)	kg	**6.5 E-2**	3.6 E-7	0.0 E+0	6.5 E-2	0.0 E+0
	Coal (in ground)	kg	**4.7 E-2**	4.9 E-2	2.9 E-4	4.3 E-2	-4.4 E-2
	Copper (Cu, ore)	kg	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Gravel (unspecified)	kg	**8.8 E-9**	8.8 E-9	0.0 E+0	0.0 E+0	0.0 E+0
	Iron (Fe, ore)	kg	**-8.5 E-4**	1.2 E-2	0.0 E+0	4.2 E-6	-1.3 E-2
	Lignite (in ground)	kg	**1.4 E-2**	1.7 E-3	0.0 E+0	1.4 E-2	-1.5 E-3
	Limestone (CaCO3, in ground)	kg	**2.2 E-2**	1.0 E-2	2.3 E-5	1.6 E-2	-4.7 E-3
	Natural Gas (in ground)	kg	**9.5 E-2**	2.8 E-2	8.9 E-4	7.2 E-2	-5.9 E-3
	Oil (in ground)	kg	**8.3 E-2**	3.4 E-2	8.9 E-3	3.7 E-2	3.5 E-3
	Sand (in ground)	kg	**1.3 E-3**	2.0 E-5	4.6 E-7	1.3 E-3	4.0 E-7
	Sodium Chloride (NaCl)	kg	**7.1 E-2**	5.5 E-2	2.1 E-7	1.6 E-2	-3.4 E-4
	Uranium (U, ore)	kg	**1.1 E-5**	3.0 E-6	4.9 E-9	8.3 E-6	-6.3 E-7
	Zinc (Zn, ore)	kg	**1.7 E-9**	1.7 E-9	0.0 E+0	0.0 E+0	0.0 E+0
	Water Used (total)	liter	**3.7 E+1**	1.2 E+0	1.8 E-1	3.6 E+1	-7.8 E-2
Air	Acenaphthene (C12H10)	g	**5.3 E-9**	7.5 E-9	1.1 E-10	6.9 E-11	-2.4 E-9
	Acenaphthylene (C12H8)	g	**5.6 E-10**	7.0 E-10	4.5 E-11	5.6 E-11	-2.4 E-10
	Acetaldehyde (CH3CHO)	g	**8.1 E-7**	8.8 E-7	8.2 E-8	2.5 E-8	-1.7 E-7
	Acetic Acid (CH3COOH)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Acetone (CH3COCH3)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Acetylene (C2H2)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Aldehyde (unspecified)	g	**1.8 E-1**	6.8 E-4	2.9 E-5	1.8 E-1	-3.8 E-4
	Alkane (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Alkene (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Alkyne (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Aluminum (Al)	g	**1.1 E-6**	3.9 E-7	4.7 E-7	1.5 E-8	2.5 E-7
	Ammonia (NH3)	g	**2.3 E-2**	1.4 E-3	4.1 E-5	2.2 E-2	-2.9 E-4
	Anthracene (C14H10)	g	**7.6 E-10**	1.0 E-9	4.3 E-11	6.9 E-11	-3.7 E-10
	Antimony (Sb)	g	**1.4 E-6**	2.3 E-6	1.2 E-8	2.3 E-7	-1.2 E-6
	AOX (Adsorbable Organic Halogens)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Aromatic Hydrocarbons (unspecified)	g	**4.3 E-3**	1.3 E-3	8.8 E-10	3.1 E-3	-7.3 E-5
	Arsenic (As)	g	**1.2 E-5**	2.4 E-5	3.0 E-7	7.1 E-6	-2.0 E-5

Table 19 (cont.)

			HP Total LC	Production	Distribution	Use	EOL
(Air (cont.)	Barium (Ba)	g	**7.4 E-7**	1.2 E-6	6.2 E-9	1.5 E-7	-6.6 E-7
	Benzaldehyde (C6H5CHO)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Benzene (C6H6)	g	**4.5 E-3**	3.8 E-3	2.8 E-4	2.1 E-3	-1.6 E-3
	Benzo(a)anthracene	g	**1.1 E-9**	1.6 E-9	2.5 E-11	4.8 E-11	-5.6 E-10
	Benzo(a)pyrene (C20H12)	g	**2.2 E-5**	3.5 E-5	3.0 E-8	3.1 E-11	-1.4 E-5
	Benzo(b)fluoranthene	g	**3.1 E-10**	4.7 E-10	9.4 E-12	4.4 E-11	-2.1 E-10
	Benzo(ghi)perylene	g	**3.8 E-10**	5.5 E-10	1.1 E-11	3.1 E-11	-2.1 E-10
	Benzo(k)fluoranthene	g	**3.1 E-10**	4.7 E-10	9.4 E-12	4.4 E-11	-2.1 E-10
	Berylium (Be)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Boron (B)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Bromium (Br)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Butane (C4H10)	g	**1.8 E-4**	2.8 E-4	1.0 E-5	5.2 E-5	-1.6 E-4
	Butane (n-C4H10)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Butene (1-CH3CH2CHCH2)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Cadmium (Cd)	g	**1.9 E-5**	6.0 E-6	3.1 E-7	1.6 E-5	-2.8 E-6
	Calcium (Ca)	g	**9.7 E-7**	3.4 E-7	4.0 E-7	1.3 E-8	2.2 E-7
	Carbon Dioxide (CO2, biomass)	g	**8.9 E+2**	1.4 E+0	1.4 E-6	8.7 E+2	1.3 E+1
	Carbon Dioxide (CO2, fossil)	g	**5.3 E+2**	2.2 E+2	3.0 E+1	3.9 E+2	-1.0 E+2
	Carbon Disulfide (CS2)	g	**5.2 E-7**	7.5 E-7	1.9 E-8	5.8 E-9	-2.6 E-7
	Carbon Monoxide (CO)	g	**6.0 E-1**	2.9 E-1	6.2 E-2	4.6 E-1	-2.1 E-1
	Carbon Tetrafluoride (CF4)	g	**9.3 E-4**	1.5 E-3	0.0 E+0	0.0 E+0	-6.0 E-4
	Chlorides (Cl-)	g	**8.6 E-5**	1.4 E-4	6.2 E-7	1.0 E-5	-6.2 E-5
	Chlorinated Matter (unspecified, as Cl)	g	**3.2 E-5**	3.2 E-5	0.0 E+0	0.0 E+0	-2.2 E-7
	Chlorine (Cl2)	g	**1.1 E-4**	7.7 E-5	1.0 E-10	6.2 E-5	-2.5 E-5
	Chrysene (C18H12)	g	**5.5 E-10**	7.6 E-10	2.4 E-11	4.9 E-11	-2.9 E-10
	Cobalt (Co)	g	**2.3 E-6**	3.9 E-6	5.5 E-8	6.2 E-7	-2.3 E-6
	Copper (Cu)	g	**-9.0 E-7**	3.0 E-6	3.5 E-8	7.5 E-8	-4.0 E-6
	Cyanide (CN-)	g	**3.6 E-6**	3.8 E-6	3.6 E-7	1.1 E-7	-7.5 E-7
	Dibenzo(a,h)anthracene	g	**2.8 E-10**	4.2 E-10	6.7 E-12	3.0 E-11	-1.7 E-10
	Dichlorobenzene (1,4-C6H4Cl2)	g	**1.0 E-7**	1.6 E-7	5.7 E-9	3.0 E-8	-9.1 E-8
	Dimethyl Benzanthracene	g	**1.3 E-9**	2.1 E-9	7.2 E-11	3.9 E-10	-1.2 E-9
	Dioxins (unspecified)	g	**3.4 E-10**	3.2 E-11	2.3 E-12	7.2 E-13	3.0 E-10
	Ethane (C2H6)	g	**2.7 E-4**	4.1 E-4	1.5 E-5	7.7 E-5	-2.4 E-4
	Ethanol (C2H5OH)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Ethylbenzene (C8H10)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Ethylene (C2H4)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0

Table 19 (cont.)

			HP Total LC	Production	Distribution	Use	EOL
Air (cont.)	Fluoranthene	g	**1.8 E-9**	2.2 E-9	1.2 E-10	1.1 E-10	-6.8 E-10
	Fluorene (C13H10)	g	**2.0 E-9**	2.5 E-9	1.5 E-10	1.1 E-10	-7.1 E-10
	Fluorides (F-)	g	**4.5 E-3**	7.4 E-3	7.0 E-8	1.2 E-6	-2.9 E-3
	Fluorine (F2)	g	**3.4 E-7**	5.5 E-7	0.0 E+0	0.0 E+0	-2.2 E-7
	Formaldehyde (CH2O)	g	**9.0 E-5**	6.5 E-5	2.8 E-5	8.8 E-6	-1.2 E-5
	Halogenated Hydrocarbons (unspecified)	g	**5.1 E-6**	5.1 E-6	4.9 E-15	8.9 E-17	4.3 E-15
	Halogenated Matter (unspecified)	g	**1.7 E-6**	1.7 E-6	0.0 E+0	2.3 E-7	-2.2 E-7
	Halon 1301 (CF3Br)	g	**9.0 E-6**	7.9 E-7	8.5 E-12	8.5 E-6	-2.9 E-7
	Heptane (C7H16)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Hexane (C6H14)	g	**1.6 E-4**	2.4 E-4	8.6 E-6	4.4 E-5	-1.4 E-4
	Hydrocarbons (except methane)	g	**6.6 E-1**	6.7 E-2	2.9 E-2	5.5 E-1	1.2 E-2
	Hydrocarbons (unspecified)	g	**3.5 E-1**	3.5 E-1	3.4 E-3	6.9 E-4	-9.0 E-5
	Hydrogen (H2)	g	**1.2 E-2**	1.2 E-2	0.0 E+0	0.0 E+0	-3.2 E-4
	Hydrogen Chloride (HCl)	g	**3.3 E-2**	2.5 E-2	1.7 E-4	2.3 E-2	-1.6 E-2
	Hydrogen Cyanide (HCN)	g	**2.4 E-5**	2.4 E-5	0.0 E+0	0.0 E+0	-2.2 E-7
	Hydrogen Fluoride (HF)	g	**2.8 E-3**	2.4 E-3	2.2 E-5	2.4 E-3	-2.0 E-3
	Hydrogen Sulfide (H2S)	g	**1.4 E-2**	1.5 E-4	7.3 E-5	1.4 E-2	-9.9 E-5
	Indeno (1,2,3,c,d) Pyrene	g	**4.7 E-10**	6.6 E-10	1.9 E-11	4.7 E-11	-2.6 E-10
	Iodine (I)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Iron (Fe)	g	**2.2 E-6**	7.6 E-7	9.0 E-7	2.8 E-8	4.9 E-7
	Isophorone	g	**8.3 E-7**	8.9 E-7	8.3 E-8	2.6 E-8	-1.7 E-7
	lanthanum (La)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Lead (Pb)	g	**5.8 E-5**	9.2 E-5	1.6 E-6	5.9 E-5	-9.5 E-5
	Magnesium (Mg)	g	**7.6 E-5**	1.6 E-4	1.6 E-6	4.8 E-5	-1.4 E-4
	Manganese (Mn)	g	**2.7 E-5**	7.4 E-5	4.8 E-7	2.7 E-5	-7.4 E-5
	Mercaptans	g	**3.8 E-3**	1.7 E-6	0.0 E+0	3.8 E-3	-2.2 E-7
	Mercury (Hg)	g	**1.1 E-5**	5.7 E-6	1.9 E-8	8.3 E-6	-2.7 E-6
	Metals (unspecified)	g	**6.9 E-3**	7.5 E-4	5.3 E-9	6.5 E-3	-3.6 E-4
	Methane (CH4)	g	**1.1 E+0**	5.3 E-1	1.8 E-2	8.8 E-1	-3.4 E-1
	Methanol (CH3OH)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Methyl Cholanthrene (3-C21H16)	g	**1.6 E-10**	2.4 E-10	8.6 E-12	4.4 E-11	-1.4 E-10
	Methyl Naphthalene (2-C11H10)	g	**2.1 E-9**	3.2 E-9	1.1 E-10	5.9 E-10	-1.8 E-9
	Molybdenum (Mo)	g	**3.8 E-7**	4.9 E-7	4.4 E-8	5.3 E-8	-2.1 E-7
	Naphthalene (C10H8)	g	**3.5 E-7**	5.5 E-7	6.8 E-9	4.9 E-8	-2.5 E-7
	Nickel (Ni)	g	**4.9 E-4**	1.2 E-4	2.8 E-6	4.2 E-4	-3.9 E-5
	Nitrogen Oxides (NOx as NO2)	g	**3.1 E+0**	8.6 E-1	2.6 E-1	2.0 E+0	-3.3 E-2

Table 19 (cont.)

			HP Total LC	Production	Distribution	Use	EOL
Air (cont.)	Nitrous Oxide (N2O)	g	**1.7 E-2**	3.2 E-3	4.5 E-3	8.2 E-3	1.5 E-3
	Organic Matter (unspecified)	g	**3.4 E-2**	3.8 E-2	1.4 E-3	3.0 E-3	-8.6 E-3
	Particulates (PM 10)	g	**1.3 E-5**	4.5 E-6	5.4 E-6	1.7 E-7	2.9 E-6
	Particulates (unspecified)	g	**1.7 E+0**	1.2 E+0	2.1 E-2	9.7 E-1	-4.8 E-1
	Pentane (C5H12)	g	**2.2 E-4**	3.5 E-4	1.2 E-5	6.4 E-5	-2.0 E-4
	Phenanthrene (C14H10)	g	**6.4 E-9**	8.0 E-9	4.8 E-10	5.4 E-10	-2.6 E-9
	Phenol (C6H5OH)	g	**2.3 E-8**	2.5 E-8	2.3 E-9	7.1 E-10	-4.8 E-9
	Phosphorus (P)	g	**3.0 E-6**	4.0 E-6	2.9 E-7	2.8 E-7	-1.5 E-6
	Phosphorus Pentoxide (P2O5)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Polycyclic Aromatic Hydrocarbons	g	**6.9 E-4**	1.1 E-3	9.8 E-13	3.0 E-5	-4.1 E-4
	Potassium (K)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Propane (C3H8)	g	**4.7 E-5**	1.1 E-4	3.6 E-8	3.8 E-5	-1.0 E-4
	Propionic Acid (CH3CH2COOH)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Propylene (CH2CHCH3)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Pyrene (C16H10)	g	**1.3 E-9**	1.8 E-9	7.4 E-11	1.4 E-10	-6.9 E-10
	Scandium (Sc)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Selenium (Se)	g	**2.1 E-6**	2.3 E-6	2.0 E-7	7.9 E-8	-4.8 E-7
	Silicon (Si)	g	**9.7 E-7**	3.4 E-7	4.0 E-7	1.3 E-8	2.2 E-7
	Sodium (Na)	g	**5.8 E-6**	2.0 E-6	2.4 E-6	7.5 E-8	1.3 E-6
	Strontium (Sr)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Sulfur Oxides (SOx as SO2)	g	**2.7 E+0**	8.0 E-1	1.2 E-1	2.1 E+0	-3.9 E-1
	Sulfuric Acid (H2SO4)	g	**1.6 E-5**	1.7 E-5	0.0 E+0	0.0 E+0	-2.2 E-7
	Tars (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Thallium (Tl)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Thorium (Th)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Tin (Sn)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Titanium (Ti)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Toluene (C6H5CH3)	g	**2.4 E-6**	3.6 E-6	7.5 E-8	3.7 E-7	-1.7 E-6
	Uranium (U)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Vanadium (V)	g	**2.3 E-5**	1.8 E-5	6.3 E-6	1.2 E-6	-2.6 E-6
	Volatile Organic Carbon (VOC)	g	**6.2 E-2**	0.0 E+0	0.0 E+0	6.2 E-2	0.0 E+0
	Xylene (C6H4(CH3)2)	g	**4.4 E-7**	7.8 E-7	2.0 E-8	2.0 E-7	-5.6 E-7
	Zinc (Zn)	g	**2.0 E-3**	1.1 E-4	8.0 E-4	1.0 E-4	9.6 E-4
	Zirconium (Zr)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0

Table 19 (cont.)

			HP Total LC	Production	Distribution	Use	EOL
Water	Acids (H+)	g	**9.7 E-4**	9.8 E-4	1.8 E-9	3.8 E-9	-1.4 E-6
	Aldehyde (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Alkane (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Alkene (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Aluminum (Al3+)	g	**3.9 E-2**	1.6 E-2	2.4 E-6	4.9 E-2	-2.7 E-2
	Ammonia (NH4+, NH3, as N)	g	**9.2 E-3**	4.1 E-3	4.5 E-4	4.4 E-3	2.9 E-4
	AOX (Adsorbable Organic Halogens)	g	**1.8 E-1**	6.7 E-6	6.3 E-12	1.8 E-1	-7.2 E-6
	Aromatic Hydrocarbons (unspecified)	g	**1.8 E-3**	1.4 E-4	1.5 E-9	1.7 E-3	-5.5 E-5
	Arsenic (As3+, As5+)	g	**7.6 E-5**	3.3 E-5	0.0 E+0	9.7 E-5	-5.4 E-5
	Barium (Ba++)	g	**7.6 E-3**	1.7 E-3	4.7 E-9	8.2 E-3	-2.3 E-3
	Barytes	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Benzene (C6H6)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	BOD5 (Biochemical Oxygen Demand)	g	**3.3 E+0**	1.5 E-2	3.1 E-3	3.3 E+0	4.1 E-4
	Boron (B III)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Cadmium (Cd++)	g	**4.6 E-6**	1.0 E-6	4.9 E-12	5.0 E-6	-1.4 E-6
	Calcium (Ca++)	g	**8.3 E-2**	8.4 E-2	0.0 E+0	0.0 E+0	-4.3 E-5
	Carbonates (CO3--, HCO3-, CO2, as C)	g	**3.2 E-4**	3.3 E-4	0.0 E+0	0.0 E+0	-9.5 E-6
	Cerium (Ce++)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Cesium (Cs++)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Chlorates (ClO3-)	g	**5.9 E-1**	6.3 E-6	0.0 E+0	5.9 E-1	0.0 E+0
	Chlorides (Cl-)	g	**5.5 E+0**	1.7 E+0	1.3 E-1	3.8 E+0	-1.5 E-1
	Chlorinated Matter (unspecified, as Cl)	g	**2.9 E-6**	1.7 E-7	0.0 E+0	2.8 E-6	-8.1 E-8
	Chlorine (Cl2)	g	**2.1 E-5**	2.2 E-5	0.0 E+0	0.0 E+0	-8.6 E-7
	Chloroform (CHCl3)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Chromate (CrO4--)	g	**3.4 E-7**	5.5 E-7	0.0 E+0	0.0 E+0	-2.2 E-7
	Chromium (Cr III)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Chromium (Cr III, Cr VI)	g	**3.7 E-4**	2.0 E-4	6.7 E-10	5.0 E-4	-3.3 E-4
	Chromium (Cr VI)	g	**7.6 E-5**	2.9 E-6	0.0 E+0	7.3 E-5	0.0 E+0
	Cobalt (Co I, Co II, Co III)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	COD (Chemical Oxygen Demand)	g	**1.5 E+1**	1.0 E-1	2.7 E-2	1.5 E+1	1.7 E-2
	Copper (Cu+, Cu++)	g	**1.9 E-4**	8.3 E-5	9.8 E-11	2.4 E-4	-1.3 E-4
	Cyanide (CN-)	g	**8.3 E-6**	1.3 E-6	6.8 E-12	7.6 E-6	-6.3 E-7
	Dissolved Matter (unspecified)	g	**5.3 E-2**	6.0 E-2	8.3 E-6	3.0 E-4	-7.3 E-3
	Dissolved Organic Carbon (DOC)	g	**1.3 E-3**	2.1 E-5	0.0 E+0	1.3 E-3	-2.3 E-5
	Ethylbenzene (C6H5C2H5)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0

Table 19 (cont.)

			HP Total LC	Production	Distribution	Use	EOL
Water (cont.)	Fluorides (F-)	g	**8.8 E-4**	1.5 E-3	7.3 E-7	3.0 E-5	-6.3 E-4
	Formaldehyde (CH2O)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Halogenated Matter (organic)	g	**4.7 E-12**	9.3 E-13	2.0 E-12	3.6 E-14	1.7 E-12
	Hexachloroethane (C2Cl6)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Hydrocarbons	g	**2.2 E-4**	2.2 E-4	0.0 E+0	0.0 E+0	0.0 E+0
	Hydrocarbons (unspecified)	g	**1.8 E-3**	1.8 E-3	8.3 E-6	2.6 E-7	3.6 E-6
	Hypochlorite (ClO-)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Hypochlorous Acid (HClO)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Inorganic Dissolved Matter (unspecified)	g	**2.2 E-5**	2.2 E-5	0.0 E+0	0.0 E+0	0.0 E+0
	Iode (I-)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Iron (Fe++, Fe3+)	g	**3.2 E-2**	7.0 E-3	6.2 E-9	3.6 E-2	-1.1 E-2
	Lead (Pb++, Pb4+)	g	**3.2 E-4**	8.3 E-5	2.0 E-11	3.7 E-4	-1.4 E-4
	Magnesium (Mg++)	g	**1.6 E-4**	1.6 E-4	0.0 E+0	0.0 E+0	-8.6 E-7
	Manganese (Mn II, Mn IV, Mn VII)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Mercury (Hg+, Hg++)	g	**9.4 E-6**	1.4 E-5	2.2 E-14	3.7 E-7	-5.3 E-6
	Metals (unspecified)	g	**2.3 E-2**	8.8 E-3	2.1 E-4	1.7 E-2	-3.0 E-3
	Methylene Chloride (CH2Cl2)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Molybdenum	g	**6.6 E-7**	6.6 E-7	0.0 E+0	0.0 E+0	0.0 E+0
	Nickel (Ni++, Ni3+)	g	**2.0 E-4**	9.1 E-5	9.8 E-12	2.4 E-4	-1.4 E-4
	Nitrate (NO3-)	g	**2.1 E-1**	1.0 E-2	1.1 E-6	2.0 E-1	-1.0 E-4
	Nitrates (NO3-)	g	**4.7 E-9**	4.7 E-9	0.0 E+0	0.0 E+0	0.0 E+0
	Nitrites (NO2-)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Nitrogenous Matter (Kjeldahl, as N)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Nitrogenous Matter (unspecified, as N)	g	**9.7 E-2**	2.1 E-3	2.6 E-10	9.5 E-2	-7.8 E-5
	Oils (unspecified)	g	**5.9 E-2**	8.0 E-3	1.9 E-3	5.0 E-2	-6.5 E-4
	Organic Dissolved Matter (chlorinated)	g	**4.5 E-5**	4.7 E-5	0.0 E+0	0.0 E+0	-2.6 E-6
	Organic Dissolved Matter (unspecified)	g	**3.5 E-3**	3.5 E-3	0.0 E+0	0.0 E+0	-2.2 E-7
	Organic Matter (unspecified)	g	**3.5 E-4**	3.5 E-4	4.6 E-9	9.9 E-9	-2.4 E-7
	Phenol (C6H5OH)	g	**4.7 E-4**	1.1 E-4	6.0 E-5	2.6 E-4	4.4 E-5
	Phosphates (as P)	g	**2.2 E-3**	1.0 E-3	9.7 E-9	1.9 E-3	-6.7 E-4
	Phosphorous Matter (unspecified, as P)	g	**1.7 E-2**	7.5 E-6	0.0 E+0	1.7 E-2	0.0 E+0
	Phosphorus (P)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Phosphorus Pentoxide (P2O5)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Polycyclic Aromatic Hydrocarbons	g	**4.0 E-5**	2.8 E-5	2.3 E-11	2.3 E-5	-1.1 E-5
	Potassium (K+)	g	**6.0 E-4**	9.4 E-4	0.0 E+0	0.0 E+0	-3.3 E-4

Table 19 (cont.)

			HP Total LC	Production	Distribution	Use	EOL
Water (cont.)	Rubidium (Rb+)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Salts (unspecified)	g	**3.7 E+0**	2.4 E-1	2.7 E-5	3.5 E+0	-1.1 E-1
	Saponifiable Oils and Fats	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Selenium (Se II, Se IV, Se VI)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Silicon Dioxide (SiO2)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Silver (Ag+)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Sodium (Na+)	g	**9.9 E-1**	7.5 E-1	1.7 E-1	5.3 E-3	6.9 E-2
	Strontium (Sr II)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Sulfate (SO4--)	g	**2.0 E+0**	1.6 E-1	1.5 E-6	2.0 E+0	-1.3 E-1
	Sulfide (S--)	g	**6.6 E-5**	1.2 E-5	1.0 E-9	5.5 E-5	-2.2 E-6
	Sulphites (SO3--)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Sulphurated Matter (unspecified, as S)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Suspended Matter (unspecified)	g	**1.7 E+0**	1.1 E-1	1.4 E-2	1.6 E+0	1.2 E-3
	Tars (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Tetrachloroethylene (C2Cl4)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Tin (Sn++, Sn4+)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Titanium (Ti3+, Ti4+)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	TOC (Total Organic Carbon)	g	**5.1 E-1**	2.8 E-3	1.5 E-8	5.1 E-1	-2.1 E-3
	Toluene (C6H5CH3)	g	**2.4 E-4**	2.0 E-5	2.2 E-10	2.2 E-4	-7.5 E-6
	Tri n-butyl-phosphate (TBP, (C4H9O)3PO)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Trichlorethane (1,1,1-CH3CCl3)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Trichloroethylene (C2HCl3)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Triethylene Glycol (C6H14O4)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Vanadium (V3+, V5+)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	VOC (Volatile Organic Compounds)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Xylene (C6H4(CH3)2)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Zinc (Zn++)	g	**4.4 E-4**	2.1 E-4	2.1 E-10	5.0 E-4	-2.7 E-4
Waste	Waste: hazardous	kg	**1.0 E-3**	1.0 E-3	1.0 E-5	1.9 E-7	7.9 E-6
	Waste: incineration	kg	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Waste: municipal and industrial	kg	**2.4 E-2**	6.2 E-3	1.7 E-5	2.0 E-2	-2.2 E-3
	Waste: total	kg	**8.9 E-2**	3.1 E-2	1.5 E-3	7.2 E-2	-1.5 E-2
	Waste: unspecified	kg	**7.2 E-3**	1.6 E-2	7.2 E-5	4.8 E-3	-1.3 E-2
	.Waste: unspecified, to incineration	kg	**2.9 E-5**	2.9 E-5	3.1 E-7	0.0 E+0	2.0 E-7
	Waste: in Landfills	kg	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Waste: Bauxite Residues (red mud)	kg	**4.8 E-7**	9.6 E-8	2.0 E-7	3.7 E-9	1.8 E-7
	Waste: FGD Sludge	kg	**4.5 E-4**	1.1 E-3	4.5 E-6	3.5 E-4	-9.6 E-4

Table 19 (cont.)

			HP Total LC	Production	Distribution	Use	EOL
Waste (cont.)	Waste: Mineral (inert)	kg	**4.8 E-2**	2.5 E-3	4.3 E-8	4.6 E-2	-9.6 E-4
	Waste: Non Mineral (inert)	kg	**4.0 E-9**	6.4 E-9	0.0 E+0	0.0 E+0	-2.4 E-9
	Waste: Non Toxic Chemicals (unspecified)	kg	**2.1 E-4**	2.1 E-4	1.0 E-8	1.8 E-10	-1.9 E-6
	Waste: Slags and Ash (unspecified)	kg	**8.0 E-3**	3.8 E-3	1.4 E-3	4.4 E-4	2.4 E-3
Energy	Feedstock Energy	MJ	**8.9 E+0**	1.3 E+0	1.4 E-2	7.7 E+0	-7.3 E-2
	Fuel Energy	MJ	**2.1 E+1**	3.5 E+0	4.1 E-1	1.9 E+1	-1.5 E+0
	Non Renewable Energy	MJ	**9.9 E+0**	4.4 E+0	4.3 E-1	6.6 E+0	-1.6 E+0
	Renewable Energy	MJ	**2.0 E+1**	3.2 E-1	3.9 E-4	2.0 E+1	-4.5 E-2
	Total Primary Energy	MJ	**3.0 E+1**	4.8 E+0	4.3 E-1	2.6 E+1	-1.6 E+0
Impacts	Acidification potential	g eq. H+	**1.5 E-1**	4.5 E-2	9.5 E-3	1.1 E-1	-1.4 E-2
	Eutrophication potential	g. eq. PO4	**8.8 E-1**	1.2 E-1	3.6 E-2	7.3 E-1	-4.3 E-3
	Resource depletion potential	MJ surplus	**9.7 E-1**	3.7 E-1	5.9 E-2	5.7 E-1	-2.4 E-2
	Global warming potential	g eq. CO2	**5.7 E+2**	2.4 E+2	3.1 E+1	4.1 E+2	-1.2 E+2
	Photochemical smog potential	g eq. ethylene	**5.0 E-1**	1.6 E-1	1.3 E-2	3.2 E-1	2.0 E-3
	Human toxicity potential	DALYs	**8.9 E-8**	1.5 E-8	1.2 E-10	8.6 E-8	-1.2 E-8

Table 20: Life Cycle Stage Contribution Life Cycle Inventory and Life Cycle Impact Assessment Results: R 96A per 100 Usable Pages (North America)

			Reman Total LC	Production	Distribution	Use	EOL
Inputs from Nature	Barium Sulfate (BaSO4, in ground)	kg	**1.5 E-7**	2.7 E-7	0.0 E+0	0.0 E+0	-1.2 E-7
	Bauxite (Al2O3, ore)	kg	**1.0 E-3**	1.1 E-2	5.4 E-7	4.5 E-4	-1.0 E-2
	Bentonite (Al2O3.4SiO2.H2O)	kg	**8.3 E-8**	8.3 E-8	0.0 E+0	0.0 E+0	0.0 E+0
	Calcium Sulfate (CaSO4, ore)	kg	**8.2 E-9**	8.2 E-9	0.0 E+0	0.0 E+0	0.0 E+0
	Clay (in ground)	kg	**6.8 E-2**	7.7 E-8	0.0 E+0	6.8 E-2	0.0 E+0
	Coal (in ground)	kg	**4.4 E-2**	1.0 E-2	1.8 E-4	4.5 E-2	-1.1 E-2
	Copper (Cu, ore)	kg	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Gravel (unspecified)	kg	**1.4 E-9**	1.4 E-9	0.0 E+0	0.0 E+0	0.0 E+0
	Iron (Fe, ore)	kg	**4.9 E-3**	4.9 E-3	0.0 E+0	4.5 E-6	-1.3 E-5
	Lignite (in ground)	kg	**1.5 E-2**	5.2 E-4	0.0 E+0	1.5 E-2	-3.1 E-5
	Limestone (CaCO3, in ground)	kg	**1.7 E-2**	1.8 E-3	1.4 E-5	1.7 E-2	-2.0 E-3
	Natural Gas (in ground)	kg	**8.7 E-2**	1.3 E-2	5.8 E-4	7.6 E-2	-2.4 E-3
	Oil (in ground)	kg	**6.8 E-2**	2.5 E-2	5.3 E-3	3.9 E-2	-1.9 E-3
	Sand (in ground)	kg	**1.3 E-3**	6.9 E-6	3.3 E-7	1.3 E-3	-5.3 E-8
	Sodium Chloride (NaCl)	kg	**6.8 E-2**	5.1 E-2	1.5 E-7	1.7 E-2	-2.4 E-4
	Uranium (U, ore)	kg	**8.9 E-6**	3.9 E-7	3.0 E-9	8.7 E-6	-2.3 E-7
	Zinc (Zn, ore)	kg	**1.0 E-10**	1.0 E-10	0.0 E+0	0.0 E+0	0.0 E+0
	Water Used (total)	liter	**3.9 E+1**	4.6 E-1	1.3 E-1	3.8 E+1	-2.1 E-2
Air	Acenaphthene (C12H10)	g	**3.3 E-10**	1.9 E-9	6.8 E-11	7.3 E-11	-1.7 E-9
	Acenaphthylene (C12H8)	g	**1.2 E-10**	1.9 E-10	2.9 E-11	5.9 E-11	-1.5 E-10
	Acetaldehyde (CH3CHO)	g	**1.5 E-7**	2.3 E-7	5.1 E-8	2.7 E-8	-1.5 E-7
	Acetic Acid (CH3COOH)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Acetone (CH3COCH3)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Acetylene (C2H2)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Aldehyde (unspecified)	g	**1.9 E-1**	3.4 E-4	1.9 E-5	1.9 E-1	-1.6 E-4
	Alkane (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Alkene (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Alkyne (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Aluminum (Al)	g	**6.3 E-7**	4.3 E-7	2.8 E-7	1.6 E-8	-9.5 E-8
	Ammonia (NH3)	g	**2.4 E-2**	9.1 E-4	2.8 E-5	2.3 E-2	-1.3 E-4
	Anthracene (C14H10)	g	**1.4 E-10**	2.7 E-10	2.8 E-11	7.2 E-11	-2.3 E-10
	Antimony (Sb)	g	**2.3 E-7**	6.0 E-7	8.0 E-9	2.5 E-7	-6.3 E-7
	AOX (Adsorbable Organic Halogens)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Aromatic Hydrocarbons (unspecified)	g	**4.6 E-3**	1.3 E-3	6.3 E-10	3.3 E-3	-2.2 E-7
	Arsenic (As)	g	**6.1 E-6**	6.5 E-6	1.9 E-7	7.5 E-6	-8.2 E-6

Table 20 (cont.)

			Reman Total LC	Production	Distribution	Use	EOL
Air (cont.)	Barium (Ba)	g	**1.4 E-7**	3.2 E-7	4.2 E-9	1.6 E-7	-3.4 E-7
	Benzaldehyde (C6H5CHO)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Benzene (C6H6)	g	**2.6 E-3**	1.0 E-3	1.9 E-4	2.2 E-3	-8.4 E-4
	Benzo(a)anthracene	g	**1.0 E-10**	4.0 E-10	1.6 E-11	5.1 E-11	-3.7 E-10
	Benzo(a)pyrene (C20H12)	g	**5.7 E-7**	1.0 E-5	2.5 E-8	3.3 E-11	-9.8 E-6
	Benzo(b)fluoranthene	g	**5.9 E-11**	1.2 E-10	6.3 E-12	4.7 E-11	-1.2 E-10
	Benzo(ghi)perylene	g	**5.1 E-11**	1.4 E-10	7.2 E-12	3.3 E-11	-1.3 E-10
	Benzo(k)fluoranthene	g	**5.9 E-11**	1.2 E-10	6.3 E-12	4.7 E-11	-1.2 E-10
	Berylium (Be)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Boron (B)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Bromium (Br)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Butane (C4H10)	g	**6.3 E-5**	7.7 E-5	6.7 E-6	5.5 E-5	-7.5 E-5
	Butane (n-C4H10)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Butene (1-CH3CH2CHCH2)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Cadmium (Cd)	g	**2.0 E-5**	4.2 E-6	2.5 E-7	1.6 E-5	-6.8 E-7
	Calcium (Ca)	g	**5.4 E-7**	3.7 E-7	2.4 E-7	1.3 E-8	-8.2 E-8
	Carbon Dioxide (CO2, biomass)	g	**9.3 E+2**	3.0 E+0	9.0 E-7	9.2 E+2	4.2 E+0
	Carbon Dioxide (CO2, fossil)	g	**4.9 E+2**	9.4 E+1	1.8 E+1	4.1 E+2	-3.7 E+1
	Carbon Disulfide (CS2)	g	**4.3 E-8**	2.1 E-7	1.2 E-8	6.1 E-9	-1.9 E-7
	Carbon Monoxide (CO)	g	**6.3 E-1**	1.1 E-1	4.9 E-2	4.8 E-1	-1.2 E-2
	Carbon Tetrafluoride (CF4)	g	**2.2 E-5**	4.5 E-4	0.0 E+0	0.0 E+0	-4.2 E-4
	Chlorides (Cl-)	g	**1.1 E-5**	3.5 E-5	4.2 E-7	1.1 E-5	-3.6 E-5
	Chlorinated Matter (unspecified, as Cl)	g	**3.6 E-6**	3.7 E-6	0.0 E+0	0.0 E+0	-1.5 E-7
	Chlorine (Cl2)	g	**6.8 E-5**	2.0 E-5	6.7 E-11	6.5 E-5	-1.8 E-5
	Chrysene (C18H12)	g	**8.9 E-11**	2.0 E-10	1.6 E-11	5.2 E-11	-1.8 E-10
	Cobalt (Co)	g	**5.9 E-7**	1.0 E-6	3.4 E-8	6.5 E-7	-1.1 E-6
	Copper (Cu)	g	**1.2 E-7**	2.4 E-7	2.1 E-8	7.9 E-8	-2.2 E-7
	Cyanide (CN-)	g	**6.8 E-7**	1.0 E-6	2.3 E-7	1.2 E-7	-6.7 E-7
	Dibenzo(a,h)anthracene	g	**4.2 E-11**	1.1 E-10	4.5 E-12	3.1 E-11	-1.0 E-10
	Dichlorobenzene (1,4-C6H4Cl2)	g	**3.6 E-8**	4.4 E-8	3.8 E-9	3.1 E-8	-4.3 E-8
	Dimethyl Benzanthracene	g	**4.7 E-10**	5.7 E-10	4.8 E-11	4.2 E-10	-5.6 E-10
	Dioxins (unspecified)	g	**1.4 E-10**	4.3 E-11	1.5 E-12	7.6 E-13	9.7 E-11
	Ethane (C2H6)	g	**9.3 E-5**	1.1 E-4	9.9 E-6	8.1 E-5	-1.1 E-4
	Ethanol (C2H5OH)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Ethylbenzene (C8H10)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Ethylene (C2H4)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0

Table 20 (cont.)

			Reman Total LC	Production	Distribution	Use	EOL
Air (cont.)	Fluoranthene	g	**3.0 E-10**	5.8 E-10	7.6 E-11	1.1 E-10	-4.7 E-10
	Fluorene (C13H10)	g	**3.5 E-10**	6.4 E-10	9.3 E-11	1.2 E-10	-5.0 E-10
	Fluorides (F-)	g	**1.1 E-4**	2.2 E-3	4.8 E-8	1.3 E-6	-2.1 E-3
	Fluorine (F2)	g	**8.0 E-9**	1.6 E-7	0.0 E+0	0.0 E+0	-1.5 E-7
	Formaldehyde (CH2O)	g	**4.4 E-5**	3.6 E-5	1.7 E-5	9.2 E-6	-1.8 E-5
	Halogenated Hydrocarbons (unspecified)	g	**7.0 E-7**	7.0 E-7	3.5 E-15	9.4 E-17	-4.9 E-16
	Halogenated Matter (unspecified)	g	**1.5 E-6**	1.4 E-6	0.0 E+0	2.4 E-7	-1.5 E-7
	Halon 1301 (CF3Br)	g	**9.7 E-6**	7.0 E-7	6.1 E-12	9.0 E-6	-2.8 E-10
	Heptane (C7H16)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Hexane (C6H14)	g	**5.4 E-5**	6.6 E-5	5.8 E-6	4.7 E-5	-6.4 E-5
	Hydrocarbons (except methane)	g	**6.7 E-1**	6.8 E-2	2.3 E-2	5.8 E-1	-3.3 E-3
	Hydrocarbons (unspecified)	g	**8.5 E-2**	8.4 E-2	2.1 E-3	7.3 E-4	-1.7 E-3
	Hydrogen (H2)	g	**1.0 E-3**	1.2 E-3	0.0 E+0	0.0 E+0	-2.3 E-4
	Hydrogen Chloride (HCl)	g	**2.5 E-2**	6.1 E-3	1.1 E-4	2.5 E-2	-6.1 E-3
	Hydrogen Cyanide (HCN)	g	**2.7 E-5**	2.7 E-5	0.0 E+0	0.0 E+0	-1.5 E-7
	Hydrogen Fluoride (HF)	g	**2.5 E-3**	6.3 E-4	1.4 E-5	2.6 E-3	-7.5 E-4
	Hydrogen Sulfide (H2S)	g	**1.4 E-2**	7.5 E-5	4.3 E-5	1.4 E-2	-1.5 E-5
	Indeno (1,2,3,c,d) Pyrene	g	**7.8 E-11**	1.7 E-10	1.2 E-11	5.0 E-11	-1.6 E-10
	Iodine (I)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Iron (Fe)	g	**1.2 E-6**	8.3 E-7	5.4 E-7	3.0 E-8	-1.8 E-7
	Isophorone	g	**1.6 E-7**	2.3 E-7	5.2 E-8	2.7 E-8	-1.6 E-7
	lanthanum (La)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Lead (Pb)	g	**7.3 E-5**	2.2 E-5	1.2 E-6	6.3 E-5	-1.4 E-5
	Magnesium (Mg)	g	**4.0 E-5**	4.3 E-5	9.9 E-7	5.1 E-5	-5.4 E-5
	Manganese (Mn)	g	**2.4 E-5**	1.6 E-5	3.0 E-7	2.8 E-5	-2.0 E-5
	Mercaptans	g	**4.0 E-3**	1.4 E-6	0.0 E+0	4.0 E-3	-1.5 E-7
	Mercury (Hg)	g	**1.0 E-5**	2.6 E-6	1.2 E-8	8.8 E-6	-1.3 E-6
	Metals (unspecified)	g	**7.4 E-3**	5.2 E-4	3.8 E-9	6.9 E-3	-9.5 E-7
	Methane (CH4)	g	**1.1 E+0**	2.1 E-1	1.2 E-2	9.3 E-1	-8.4 E-2
	Methanol (CH3OH)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Methyl Cholanthrene (3-C21H16)	g	**5.4 E-11**	6.6 E-11	5.8 E-12	4.7 E-11	-6.4 E-11
	Methyl Naphthalene (2-C11H10)	g	**7.2 E-10**	8.7 E-10	7.7 E-11	6.2 E-10	-8.6 E-10
	Molybdenum (Mo)	g	**1.1 E-7**	1.6 E-7	2.7 E-8	5.6 E-8	-1.3 E-7
	Naphthalene (C10H8)	g	**5.6 E-8**	1.4 E-7	4.5 E-9	5.1 E-8	-1.4 E-7
	Nickel (Ni)	g	**5.1 E-4**	8.2 E-5	1.7 E-6	4.4 E-4	-9.9 E-6
	Nitrogen Oxides (NOx as NO2)	g	**2.8 E+0**	5.3 E-1	2.1 E-1	2.2 E+0	-1.1 E-1

Table 20 (cont.)

			Reman Total LC	Production	Distribution	Use	EOL
Air (cont.)	Nitrous Oxide (N2O)	g	**1.4 E-2**	3.8 E-3	2.4 E-3	8.7 E-3	-7.8 E-4
	Organic Matter (unspecified)	g	**1.8 E-2**	1.8 E-2	9.1 E-4	3.2 E-3	-4.4 E-3
	Particulates (PM 10)	g	**7.2 E-6**	4.9 E-6	3.2 E-6	1.8 E-7	-1.1 E-6
	Particulates (unspecified)	g	**1.1 E+0**	2.9 E-1	1.3 E-2	1.0 E+0	-2.4 E-1
	Pentane (C5H12)	g	**7.8 E-5**	9.5 E-5	8.3 E-6	6.8 E-5	-9.3 E-5
	Phenanthrene (C14H10)	g	**1.3 E-9**	2.1 E-9	3.0 E-10	5.7 E-10	-1.7 E-9
	Phenol (C6H5OH)	g	**4.3 E-9**	6.4 E-9	1.4 E-9	7.5 E-10	-4.3 E-9
	Phosphorus (P)	g	**6.5 E-7**	1.2 E-6	1.7 E-7	3.0 E-7	-1.0 E-6
	Phosphorus Pentoxide (P2O5)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Polycyclic Aromatic Hydrocarbons	g	**8.0 E-5**	3.4 E-4	7.0 E-13	3.2 E-5	-2.9 E-4
	Potassium (K)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Propane (C3H8)	g	**3.0 E-5**	3.0 E-5	2.2 E-8	4.0 E-5	-4.1 E-5
	Propionic Acid (CH3CH2COOH)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Propylene (CH2CHCH3)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Pyrene (C16H10)	g	**2.5 E-10**	4.8 E-10	4.7 E-11	1.5 E-10	-4.2 E-10
	Scandium (Sc)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Selenium (Se)	g	**4.0 E-7**	6.1 E-7	1.3 E-7	8.3 E-8	-4.1 E-7
	Silicon (Si)	g	**5.4 E-7**	3.7 E-7	2.4 E-7	1.3 E-8	-8.2 E-8
	Sodium (Na)	g	**3.2 E-6**	2.2 E-6	1.4 E-6	8.0 E-8	-4.9 E-7
	Strontium (Sr)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Sulfur Oxides (SOx as SO2)	g	**2.5 E+0**	3.3 E-1	1.0 E-2	2.3 E+0	-8.3 E-2
	Sulfuric Acid (H2SO4)	g	**1.3 E-6**	1.4 E-6	0.0 E+0	0.0 E+0	-1.5 E-7
	Tars (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Thallium (Tl)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Thorium (Th)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Tin (Sn)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Titanium (Ti)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Toluene (C6H5CH3)	g	**4.5 E-7**	9.4 E-7	4.9 E-8	3.9 E-7	-9.3 E-7
	Uranium (U)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Vanadium (V)	g	**9.4 E-6**	9.0 E-6	3.7 E-6	1.2 E-6	-4.6 E-6
	Volatile Organic Carbon (VOC)	g	**7.0 E-2**	0.0 E+0	0.0 E+0	7.0 E-2	0.0 E+0
	Xylene (C6H4(CH3)2)	g	**1.9 E-7**	2.1 E-7	1.3 E-8	2.1 E-7	-2.4 E-7
	Zinc (Zn)	g	**1.6 E-3**	8.1 E-4	6.6 E-4	1.1 E-4	-4.0 E-6
	Zirconium (Zr)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0

Table 20 (cont.)

			Reman Total LC	Production	Distribution	Use	EOL
Water	Acids (H+)	g	**9.8 E-4**	9.8 E-4	1.2 E-9	4.0 E-9	-9.7 E-7
	Aldehyde (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Alkane (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Alkene (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Aluminum (Al3+)	g	**5.2 E-2**	3.3 E-4	1.7 E-6	5.2 E-2	-2.6 E-5
	Ammonia (NH4+, NH3, as N)	g	**9.5 E-3**	4.6 E-3	3.3 E-4	4.6 E-3	-5.7 E-5
	AOX (Adsorbable Organic Halogens)	g	**1.9 E-1**	5.4 E-7	4.5 E-12	1.9 E-1	-6.8 E-9
	Aromatic Hydrocarbons (unspecified)	g	**1.9 E-3**	1.3 E-4	1.1 E-9	1.8 E-3	-5.2 E-8
	Arsenic (As3+, As5+)	g	**1.0 E-4**	7.4 E-7	0.0 E+0	1.0 E-4	-5.1 E-8
	Barium (Ba++)	g	**9.0 E-3**	3.9 E-4	3.4 E-9	8.7 E-3	-2.2 E-6
	Barytes	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Benzene (C6H6)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	BOD5 (Biochemical Oxygen Demand)	g	**3.5 E+0**	1.1 E-2	2.3 E-3	3.5 E+0	-3.2 E-4
	Boron (B III)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Cadmium (Cd++)	g	**5.4 E-6**	1.8 E-7	3.5 E-12	5.3 E-6	-1.4 E-9
	Calcium (Ca++)	g	**9.9 E-3**	9.9 E-3	0.0 E+0	0.0 E+0	-3.1 E-5
	Carbonates (CO3--, HCO3-, CO2, as C)	g	**4.9 E-5**	5.6 E-5	0.0 E+0	0.0 E+0	-6.7 E-6
	Cerium (Ce++)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Cesium (Cs++)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Chlorates (ClO3-)	g	**6.2 E-1**	0.0 E+0	0.0 E+0	6.2 E-1	0.0 E+0
	Chlorides (Cl-)	g	**4.4 E+0**	3.5 E-1	7.6 E-2	4.0 E+0	-4.5 E-2
	Chlorinated Matter (unspecified, as Cl)	g	**3.1 E-6**	1.4 E-7	0.0 E+0	3.0 E-6	-7.7 E-11
	Chlorine (Cl2)	g	**2.4 E-6**	3.0 E-6	0.0 E+0	0.0 E+0	-6.1 E-7
	Chloroform (CHCl3)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Chromate (CrO4--)	g	**8.0 E-9**	1.6 E-7	0.0 E+0	0.0 E+0	-1.5 E-7
	Chromium (Cr III)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Chromium (Cr III, Cr VI)	g	**5.3 E-4**	4.4 E-6	4.6 E-10	5.3 E-4	-3.1 E-7
	Chromium (Cr VI)	g	**7.8 E-5**	3.2 E-7	0.0 E+0	7.7 E-5	0.0 E+0
	Cobalt (Co I, Co II, Co III)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	COD (Chemical Oxygen Demand)	g	**1.6 E+1**	7.1 E-2	1.9 E-2	1.6 E+1	-2.7 E-3
	Copper (Cu+, Cu++)	g	**2.5 E-4**	3.2 E-6	7.0 E-11	2.5 E-4	-2.8 E-7
	Cyanide (CN-)	g	**8.6 E-6**	7.3 E-7	4.9 E-12	8.1 E-6	-1.5 E-7
	Dissolved Matter (unspecified)	g	**1.5 E-2**	2.0 E-2	5.2 E-6	3.1 E-4	-4.9 E-3
	Dissolved Organic Carbon (DOC)	g	**1.3 E-3**	8.1 E-6	0.0 E+0	1.3 E-3	-2.2 E-8
	Ethylbenzene (C6H5C2H5)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Fluorides (F-)	g	**4.4 E-5**	4.3 E-4	4.6 E-7	3.1 E-5	-4.2 E-4

Table 20 (cont.)

			Reman Total LC	Production	Distribution	Use	EOL
Water (cont.)	Formaldehyde (CH2O)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Halogenated Matter (organic)	g	**3.1 E-12**	1.9 E-12	1.4 E-12	3.7 E-14	-2.0 E-13
	Hexachloroethane (C2Cl6)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Hydrocarbons	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Hydrocarbons (unspecified)	g	**1.3 E-3**	1.3 E-3	4.9 E-6	2.8 E-7	-2.3 E-6
	Hypochlorite (ClO-)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Hypochlorous Acid (HClO)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Inorganic Dissolved Matter (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Iode (I-)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Iron (Fe++, Fe3+)	g	**3.8 E-2**	4.5 E-4	4.3 E-9	3.8 E-2	-1.1 E-5
	Lead (Pb++, Pb4+)	g	**4.0 E-4**	2.6 E-6	1.4 E-11	3.9 E-4	-1.3 E-7
	Magnesium (Mg++)	g	**3.2 E-5**	3.3 E-5	0.0 E+0	0.0 E+0	-6.1 E-7
	Manganese (Mn II, Mn IV, Mn VII)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Mercury (Hg+, Hg++)	g	**1.8 E-6**	5.1 E-6	1.6 E-14	3.9 E-7	-3.6 E-6
	Metals (unspecified)	g	**2.3 E-2**	4.6 E-3	1.3 E-4	1.8 E-2	-4.3 E-5
	Methylene Chloride (CH2Cl2)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Molybdenum	g	**7.5 E-7**	7.5 E-7	0.0 E+0	0.0 E+0	0.0 E+0
	Nickel (Ni++, Ni3+)	g	**2.6 E-4**	3.4 E-6	7.0 E-12	2.6 E-4	-2.8 E-7
	Nitrate (NO3-)	g	**2.2 E-1**	7.6 E-3	7.4 E-7	2.1 E-1	-7.9 E-6
	Nitrates (NO3-)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Nitrites (NO2-)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Nitrogenous Matter (Kjeldahl, as N)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Nitrogenous Matter (unspecified, as N)	g	**1.0 E-1**	4.3 E-4	1.9 E-10	1.0 E-1	-6.9 E-7
	Oils (unspecified)	g	**6.0 E-2**	6.8 E-3	1.3 E-3	5.3 E-2	-5.5 E-4
	Organic Dissolved Matter (chlorinated)	g	**1.5 E-6**	3.3 E-6	0.0 E+0	0.0 E+0	-1.8 E-6
	Organic Dissolved Matter (unspecified)	g	**3.9 E-3**	3.9 E-3	0.0 E+0	0.0 E+0	-1.5 E-7
	Organic Matter (unspecified)	g	**3.8 E-5**	3.8 E-5	3.1 E-9	1.0 E-8	-1.7 E-7
	Phenol (C6H5OH)	g	**4.5 E-4**	1.3 E-4	4.4 E-5	2.8 E-4	-6.7 E-6
	Phosphates (as P)	g	**2.2 E-3**	2.4 E-4	7.0 E-9	2.0 E-3	-6.7 E-7
	Phosphorous Matter (unspecified, as P)	g	**1.8 E-2**	8.4 E-6	0.0 E+0	1.8 E-2	0.0 E+0
	Phosphorus (P)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Phosphorus Pentoxide (P2O5)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Polycyclic Aromatic Hydrocarbons	g	**2.7 E-5**	9.6 E-6	1.7 E-11	2.4 E-5	-7.3 E-6
	Potassium (K+)	g	**2.0 E-5**	2.6 E-4	0.0 E+0	0.0 E+0	-2.4 E-4
	Rubidium (Rb+)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0

Table 20 (cont.)

			Reman Total LC	Production	Distribution	Use	EOL
Water (cont.)	Salts (unspecified)	g	**3.9 E+0**	2.0 E-1	1.9 E-5	3.7 E+0	-1.1 E-4
	Saponifiable Oils and Fats	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Selenium (Se II, Se IV, Se VI)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Silicon Dioxide (SiO2)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Silver (Ag+)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Sodium (Na+)	g	**3.0 E-1**	2.4 E-1	9.8 E-2	5.6 E-3	-4.8 E-2
	Strontium (Sr II)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Sulfate (SO4--)	g	**2.1 E+0**	6.3 E-2	1.1 E-6	2.1 E+0	-1.0 E-3
	Sulfide (S--)	g	**7.1 E-5**	1.2 E-5	7.0 E-10	5.8 E-5	-1.6 E-7
	Sulphites (SO3--)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Sulphurated Matter (unspecified, as S)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Suspended Matter (unspecified)	g	**1.7 E+0**	3.9 E-2	1.0 E-2	1.7 E+0	-5.7 E-3
	Tars (unspecified)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Tetrachloroethylene (C2Cl4)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Tin (Sn++, Sn4+)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Titanium (Ti3+, Ti4+)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	TOC (Total Organic Carbon)	g	**5.4 E-1**	1.7 E-3	1.1 E-8	5.4 E-1	-2.0 E-6
	Toluene (C6H5CH3)	g	**2.5 E-4**	1.7 E-5	1.5 E-10	2.4 E-4	-7.1 E-9
	Tri n-butyl-phosphate (TBP, (C4H9O)3PO)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Trichlorethane (1,1,1-CH3CCl3)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Trichloroethylene (C2HCl3)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Triethylene Glycol (C6H14O4)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Vanadium (V3+, V5+)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	VOC (Volatile Organic Compounds)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Xylene (C6H4(CH3)2)	g	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Zinc (Zn++)	g	**5.3 E-4**	6.0 E-6	1.5 E-10	5.3 E-4	-4.1 E-7
Waste	Waste: hazardous	kg	**2.7 E-5**	2.1 E-5	7.4 E-6	2.0 E-7	-1.9 E-6
	Waste: incineration	kg	**0.0 E+0**	0.0 E+0	0.0 E+0	0.0 E+0	0.0 E+0
	Waste: municipal and industrial	kg	**2.1 E-2**	2.2 E-3	1.2 E-5	2.1 E-2	-1.6 E-3
	Waste: total	kg	**1.2 E-1**	1.9 E-2	9.5 E-4	7.6 E-2	2.1 E-2
	Waste: unspecified	kg	**3.9 E-3**	4.1 E-3	4.5 E-5	5.1 E-3	-5.4 E-3
	.Waste: unspecified, to incineration	kg	**2.3 E-5**	2.3 E-5	1.9 E-7	0.0 E+0	-5.3 E-8
	Waste: in Landfills	kg	**3.9 E-2**	9.9 E-3	0.0 E+0	0.0 E+0	2.9 E-2
	Waste: Bauxite Residues (red mud)	kg	**3.2 E-7**	2.0 E-7	1.5 E-7	3.9 E-9	-2.0 E-8
	Waste: FGD Sludge	kg	**2.8 E-4**	2.8 E-4	2.8 E-6	3.7 E-4	-3.8 E-4
	Waste: Mineral (inert)	kg	**4.9 E-2**	3.8 E-4	3.1 E-8	4.9 E-2	-1.6 E-5

Table 20 (cont.)

			Reman Total LC	Production	Distribution	Use	EOL
Waste	Waste: Non Mineral (inert)	kg	**8.9 E-11**	1.8 E-9	0.0 E+0	0.0 E+0	-1.7 E-9
	Waste: Non Toxic Chemicals (unspecified)	kg	**3.0 E-5**	3.2 E-5	7.3 E-9	1.9 E-10	-1.3 E-6
	Waste: Slags and Ash (unspecified)	kg	**3.9 E-3**	2.4 E-3	8.9 E-4	4.6 E-4	1.1 E-4
Energy	Feedstock Energy	MJ	**8.8 E+0**	6.9 E-1	7.8 E-3	8.2 E+0	-3.8 E-2
	Fuel Energy	MJ	**2.1 E+1**	1.4 E+0	2.5 E-1	2.0 E+1	-6.0 E-1
	Non Renewable Energy	MJ	**8.4 E+0**	1.8 E+0	2.6 E-1	7.0 E+0	-6.2 E-1
	Renewable Energy	MJ	**2.1 E+1**	3.0 E-1	2.4 E-4	2.1 E+1	-1.5 E-2
	Total Primary Energy	MJ	**2.9 E+1**	2.1 E+0	2.6 E-1	2.8 E+1	-6.4 E-1
Impacts	Acidification potential	g eq. H+	**1.4 E-1**	2.2 E-2	4.8 E-3	1.2 E-1	-5.3 E-3
	Eutrophication potential	g. eq. PO4	**8.5 E-1**	7.5 E-2	2.8 E-2	7.7 E-1	-1.5 E-2
	Resource depletion potential	MJ surplus	**8.2 E-1**	2.2 E-1	3.5 E-2	6.0 E-1	-3.0 E-2
	Global warming potential	g eq. CO2	**5.2 E+2**	1.0 E+2	1.9 E+1	4.4 E+2	-4.2 E+1
	Photochemical smog potential	g eq. ethylene	**4.1 E-1**	6.3 E-2	1.0 E-2	3.4 E-1	-2.9 E-3
	Human toxicity potential	DALYs	**9.5 E-8**	5.8 E-9	8.0 E-11	9.0 E-8	-6.6 E-10