LIFE CYCLE ASSESSMENT COMPARING LAUNDERED SURGICAL GOWNS WITH POLYPROPYLENE BASED DISPOSABLE GOWNS

This Report has been prepared for The Australian Industry Group and the Textile Rental and Laundry Association (Victoria) by the Centre for Design at RMIT University

Prepared by:
Andrew Carre

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Executive Summary

The goal of this report was to compare the potential environmental impacts of reusable laundered surgical gowns with single use, polypropylene disposable gowns using the Life Cycle Assessment (LCA) technique, as defined in ISO 14040. In accordance with ISO14044, this study has been peer reviewed to the standard.

The report was undertaken by the Centre for Design at RMIT at the request of the Australian Industry Group and the Textile Rental and Laundry Association (Victoria). The report was undertaken pursuant to Sustainability Covenant made by The Australian Industry Group and the Victorian Environmental Protection Authority and Victorian State Government as an approved project.

Unit of comparison

Surgical gowns are supplied to hospitals in sterile packs that contain a gown and towel (huck towel). These packs come wrapped and sealed to protect against infection. For this study the functional unit (or unit of comparison) was deemed to be the single use of a gown and towel pack when undertaking a surgical procedure.

The study endeavoured to encompass all of the potential environmental impacts associated with the supply of the functional unit (one single use sterile pack containing gown and huck towel).

Results

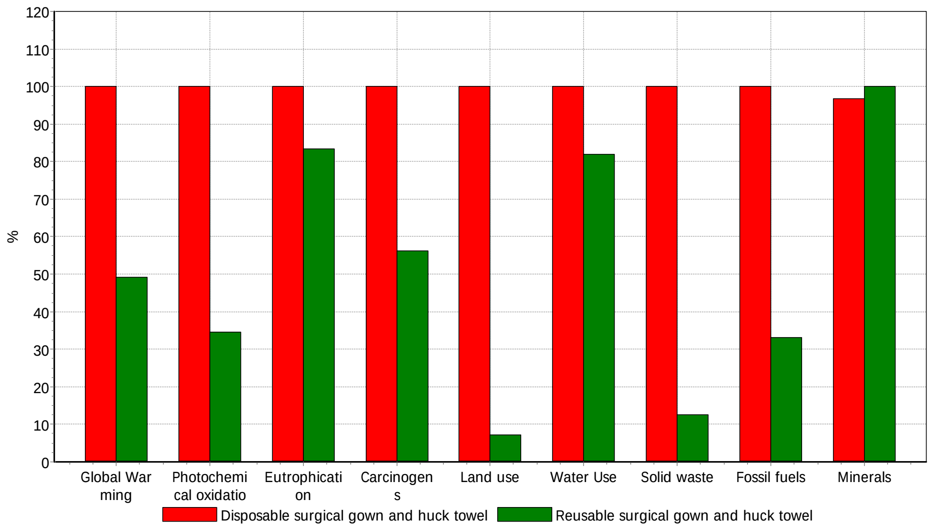

Figure 0-1 Comparison of life cycle impacts of disposable versus reusable surgical packs.

Table 0-1 Characterisation of life cycle impacts per surgical pack use.

Impact category	Unit	Disposable pack	Reusable pack
Global Warming	kg CO2	1.0E+00	5.1E-01
Photochemical oxidation	kg C2H4	4.6E-04	1.6E-04
Eutrophication	kg PO4--- eq	5.5E-04	4.6E-04
Carcinogens	DALY	1.3E-08	7.6E-09
Land use	Ha a	2.4E-05	1.7E-06
Water Use	KL H2O	1.4E-02	1.1E-02
Solid waste	kg	3.4E-01	4.3E-02
Fossil fuels	MJ surplus	1.9E+00	6.4E-01
Minerals	MJ Surplus	1.0E-03	1.1E-03

Overall, reusable gowns were found to generate lesser environmental impacts in the global warming, photochemical oxidation, eutrophication, carcinogens, land use, water use, solid waste, fossil fuels. Disposable gowns faired better in the minerals category (refer Figure 0-1). To aid in interpreting the characterisation results, equivalent units were developed that are shown at the base of this executive summary (refer Table 0-2, at the base of this executive summary).

In general, disposable gowns had higher impacts in most categories because environmental impacts associated with gown manufacture were incurred for each gown use. This is in contrast to the reusable gown life cycle, which although incurring washing impacts, the gown survives over multiple uses (127 uses on average) so only a small portion of manufacturing impacts are incurred at each use.

Although disposable gowns performed better in the mineral scarcity indicator, the reduction versus a reusable gown and towel pack was minimal. Normalised results also suggest that mineral impacts form a far smaller proportion of the total per-capita impact of the average Australian, than some of the other indicators considered (refer Figure 0-2).

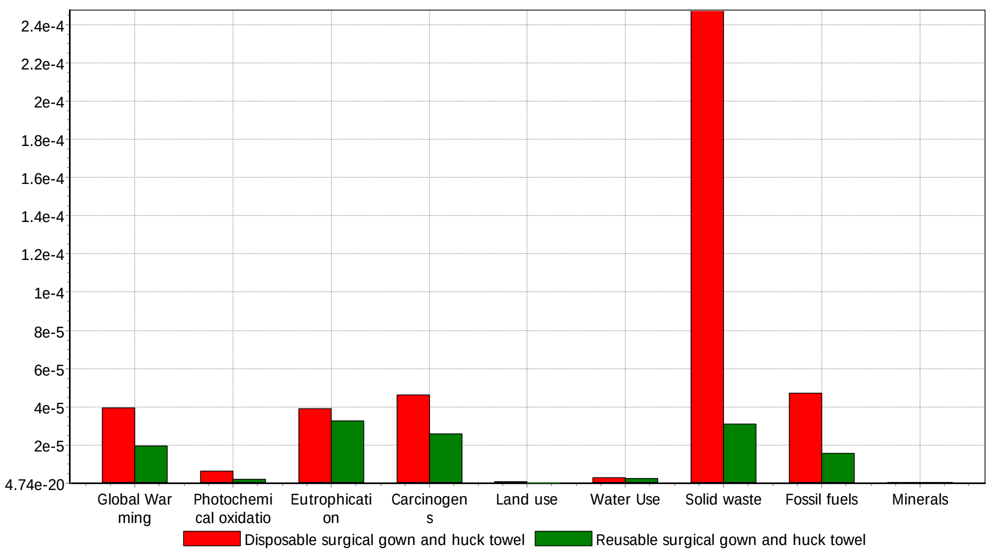

Figure 0-2 Comparison of life cycle impacts of disposable versus reusable surgical packs (normalised results – Australian per capita).

Although the disposable gown was shown to consume water to a greater degree than the reusable gown, concluding as to the exact nature of environmental damage in this indicator is difficult. The consumption of water associated with the disposable gown is largely driven by manufacturing in the United States, however water consumption of the reusable gown is largely associated with water consumed locally in the washing process.

Opportunities were found to reduce the environmental impacts of both reusable and disposable gowns. Reusable gown impacts could be improved by:

- Manufacturing the huck towel out of a polyester blend material (similar to the gown)
- Integrating huck towel and non-woven wrap functionality
- Minimising disposable components
- Ensuring Recycling type technology is applied at all laundries
- Considering waste water processing to extract phosphates

Disposable gown impacts could be improved by ensuring gowns are recycled at the end of their lives.

Although extensive information was available regarding the reusable surgical gown life cycle, very little information was supplied with respect to the disposable gown life cycle. For this reason the Life Cycle Inventory had to be constructed largely from industry survey results and publicly available data for disposable gowns, which is not as robust as actual process data. For this reason a number of sensitivity analyses were undertaken that attempt to address uncertainties in assumptions made, and to verify the appropriateness of conclusions drawn

In conclusion, the reusable gown was shown to generate reduced environmental impacts versus the disposable gown in most impact indicators considered. The reduced impacts of the reusable gown were primarily associated with the extended life of the gown, which in turn reduces the manufacturing impacts associated with each gown use. In contrast, the disposable gown's manufacturing impacts are fully incurred each time a gown is used.

Limitations of findings

This LCA study has compared the life cycle impacts of reusable surgical gowns with disposable gowns using data provided by reusable gown and disposable gown industry participants. Data quality achieved is believed to be suitable for the general comparison of systems in a typical urban application and provides directional guidance as to the impacts involved. Detailed quantification of impacts will vary between specific applications.

It should be noted that the base case reusable system assessed includes water recycling, which may not be applied in all cases. Users of reusable gowns should ensure that laundry processes incorporate water recycling systems.

Low phosphate detergents were also assumed in this study which may not be used by all laundry service providers. Use of traditional, high phosphate detergents significantly increases eutrophication impacts of the reusable gown above those of the disposable gown shown in this study (other indicators would not be significantly affected). Users considering reusable products should ensure that low phosphate detergents are being used.

Finally, it is believed that further work could be undertaken to improve the quality of data used in this study. An area where data could be further improved would be in the manufacture of non-woven fabrics used in disposable gowns.

* *Equivalent units*[1]

The following equivalent units were developed to help interpret the characterisation results presented in Table 0-1 above. The chart restates the results in Table 0-1 in more readily recognisable units.

Table 0-2 Characterisation result restated in equivalent units.

Impact category	Factor*	Unit	Disposable pack	Reusable pack
Global Warming	20	Ballons	20.6	10.1
Photochemical oxidation	1255511	m car travel	572.5	198.0
Eutrophication	80283	litres grey water	44.5	37.1
Carcinogens	76	kg arsenic	0.000001	0.000001
Land use	0.5	Footy fields	0.000012	0.000001
Water Use	100	buckets	1.4	1.1
Solid waste	1	kg waste	0.34	0.04
Fossil fuels	0.007	household energy days	0.014	0.005
Minerals	0.007	household energy days	0.00001	0.00001

[1] Note: Although this study has been peer reviewed, the equivalent units table was added following the peer review so has not been peer reviewed.

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1. Introduction

This report was undertaken by the Centre for Design at RMIT at the request of the Australian Industry Group and the Textile Rental and Laundry Association (Victoria). The report was undertaken pursuant to Sustainability Covenant made by The Australian Industry Group and the Victorian Environmental Protection Authority and Victorian State Government as an approved project.

1.1 Involved parties

The study was undertaken with the involvement of parties as follows:

Commissioning party: The Australian Industry Group: “The Australian Industry Group (AI Group) is a leading industry association in Australia. Ai Group member businesses employ around 750,000 staff in an expanding range of industry sectors including: manufacturing, engineering, construction, defence, call centres, labour hire, transport, logistics, utilities, infrastructure, environmental products and services and business services” (2008)

Participating parties:

Textile Rental and Laundry Association (Victoria): “Textile Rental and Laundry Association Australia Ltd is the peak body of state laundry associations, whose members service the textile rental, laundry and linen supply needs of hospitality, health care, manufacturing and other industries, as well as the domestic market.” (TRLA 2008)

Sample of disposable gown manufacturers: A sample of disposable gown manufacturers were surveyed locally (refer Appendix B).

A disposable gown manufacturer initially agreed to participate in the study, but later withdrew, citing restructuring issues associated with its parent company.

1.2 ISO14044 review

Under ISO14044 it is necessary to:

a) conduct a third part review of the Life Cycle Assessment report, and;
b) engage interested parties in the review of Life Cycle Assessment studies that are intended to be used in comparative assertions (ISO14044: paragraph 4.2.3.7).

In this study it was elected to have an independent, external, life cycle assessment expert undertake the peer review of the report.

A concerted attempt was made to involve interested parties in the study, which initially involved a representative from the disposable gown manufacturing industry and a representative from the laundered gown industry. Such involvement was formalised via a participation agreement, however due to internal corporate structural issues, the representative from the disposable gown manufacturing industry later withdrew from the study. In order to ensure that disposable gown manufacturing interests were acknowledged in the report, a survey was developed that described the functional unit comparison basis and a subset of study results (specific to disposable gowns). This survey was sent to key members of the industry and findings were incorporated into the study.

Findings from the survey along with how those findings were incorporated into the report are detailed in Appendix B.

2. Goal and scope

2.1 Goal

The goal of this report is to compare the potential environmental impacts of reusable laundered surgical gowns with single use, polypropylene disposable gowns using the Life Cycle Assessment (LCA) technique, as defined in ISO 14040 series and as summarised in Appendix A.

This report considers surgical gowns worn by medical practitioners in hospitals when undertaking theatre procedures. The gowns are an apron-type design that provide a level of protection for the wearer from liquid spills during a procedure. Gowns are supplied sterilised, so they also function to protect the individual undergoing the surgical procedure and the wearer from infection transfer.

The audience is intended to be the general public, so peer review is required as defined by ISO 14044 (2006).

2.2 Scope of this report

This report considers the potential environmental impacts of processes within the system boundary described in Section 2.3 and using the assessment method described in Section 3.3.

2.2.1 Local versus global impacts

In assessing potential environmental impacts, the study does not differentiate between local and global impacts. For certain environmental indicators, such as water use, this can be important because water may be scarce locally, but not scarce at foreign locations (although there is a growing body of evidence suggesting water is becoming a global issue). Other environmental impacts, such as global warming, can be considered of equal importance both locally and at foreign locations.

2.2.2 Clinical efficacy

Clinical efficacy is not addressed directly by the study, other than ensuring that gowns compared meet minimum standards as defined by the functional unit. One measure identified as important to achieving clinical performance is liquid bleed through, which is defined by a Australian and international standards.

2.2.3 Infrastructure

Capital infrastructure included in the study:

- Transport
- Energy generation
- Fuel extraction
- Fuel refining
- Raw material extraction
- Raw material processing
- Waste processing
- Reusable gown fabric manufacturing infrastructure
- Equipment included associated with the laundry facility was included (refer Appendix D)

Capital infrastructure excluded from the study due to lack of information:

- Gown manufacture (sewing) for both reusable and disposable gowns
- Equipment and buildings associated with disposable gown distribution
- Equipment and buildings associated with disposable gown fabric manufacture

2.3 System boundary

The study endeavours to encompass all of the environmental impacts associated with the supply of the functional unit (one single use sterile pack containing gown and huck towel). The boundaries differ between disposable and reusable gowns due to the distinctly different nature of the systems involved.

The system boundary selected for the reusable pack is shown in Figure 2-1. The system boundary selected for the disposable pack is shown in Figure 2-2. Both diagrams describe the process flows considered, as well as those processes excluded from the study.

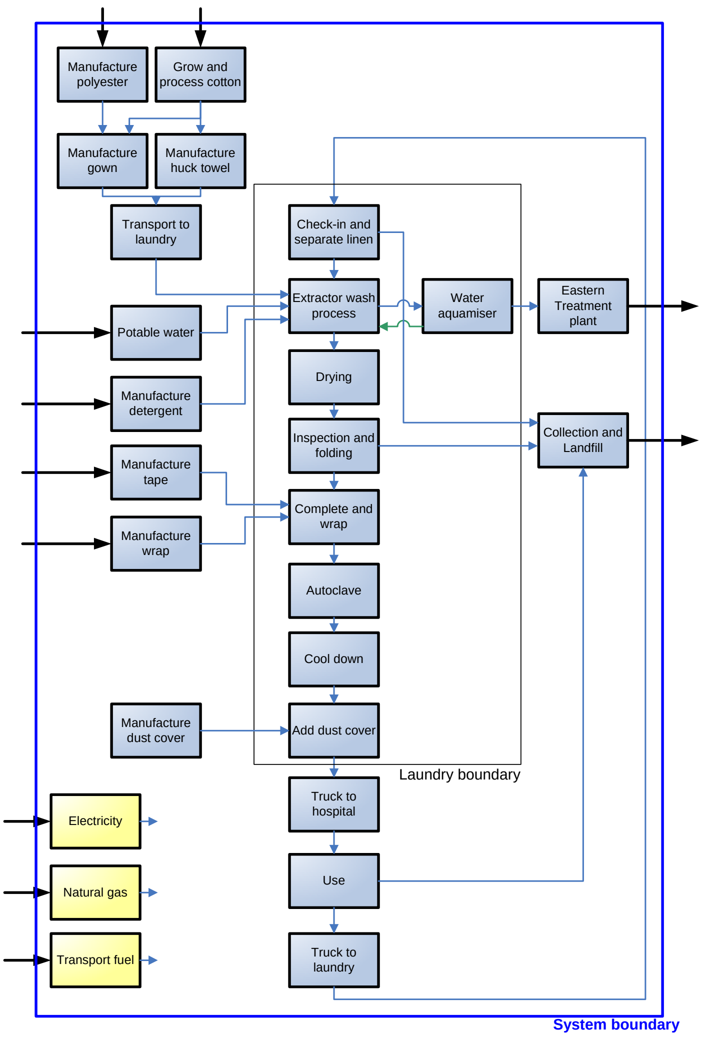

Figure 2-1 System boundary for reusable gown and huck towel pack.

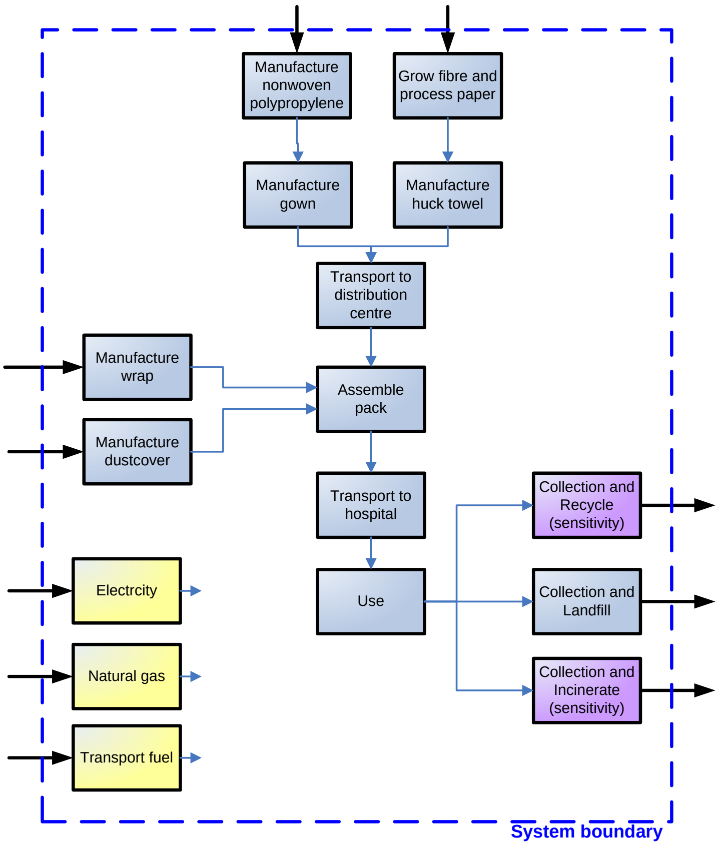

Figure 2-2 System boundary for disposable gown and huck towel pack.

Both system boundaries encompass unit processes employed from resource extraction, manufacture of materials, manufacture of gowns, processing of gowns, transport to users and reprocessing and disposal. Agricultural processes, such as those used to grow cotton are also included, as are those processes that occur at the end of gown life such as breakdown within landfill, recycling (sensitivity study only) and incineration (sensitivity study only).

2.4 Functional unit

Surgical gowns are supplied to hospitals in sterile packs that contain a gown and towel (huck towel). These packs come wrapped and sealed to protect against infection. **For this study the functional unit was deemed to be the single use of a gown and towel pack when undertaking a surgical procedure.** In using the gown it must provide functional performance as follows:

i) <u>user protection from liquid bleed through</u>
Protection from bleed through was defined in terms of the water penetration test AS2001.2.17 (Standards Australia 1997). The performance required of a reusable gown in AS3789.8 (Standards Australia 1997) is a minimum performance of 3.0kPa (pressure required to move water though fabric during test).

ii) <u>sterile garment</u>

The garment is assumed to comply with AS4187 (Standards Australia 1998) requirements for sterilisation.

Beyond these elements it is assumed that the gown provides the user with equivalent neck to knee coverage.

No specific requirements for the towel were noted, other than it should be absorbent and readily used to dry hands etc.

Unfortunately, there is no functionally based standard that governs surgical gowns in Australia. Although standards such as AS3789.8 (Standards Australia 1997) call out numerous requirements beyond those listed above, these mainly refer to the fabric from which a reusable gown can be constructed and may refer more to durability than functional performance.

This study assumes that a sterilised reusable garment provides the same level of clinical performance as a disposable garment.

2.5 Functions not considered in the functional unit

The above functional unit was selected to best address the actual use of gowns in Australia, subject to Australian performance standards. However, for certain disposable gowns, performance characteristics such as prevention of liquid bleed through may exceed those described by the functional unit. In particular, many of the disposable gown systems are designed to comply with European gown standards, that set more stringent performance requirements for characteristics such as liquid bleed through (refer Table 2-1).

Table 2-1 Australian and European water penetration test requirements compared

AS3789.8	All			
	3kPa min (31.5 cm H2O)			
EN 13795-3	Standard performance		High performance	
	Critical area	Less critical area	Critical area	Less critical area
	>20cm H2O	>10 cm H2O	>100 cm H2O	>10 cm H2O

Whether the additional performance (in the case of the high performance requirement described in the European standard) is necessary in order to deliver the core function of the gown remains to be seen in an Australian context. Hence the decision in this study to set functional performance requirements in accordance with applicable standards, in this case Australian.

With reference to Table 2-1, it is reasonable to expect that a standard performance gown under EN13795-3 may not comply with AS3789.8 as bleed through pressures are lower for a standard gown under EN13795-3. Hence for the purposes of this study, a reusable gown compliant with AS3789.8 was compared with a disposable gown compliant with the high performance EN13795-3 standard. This suggests that some excess bleed-through protection is provided by the disposable gown (in critical areas only).

The existence of excess protection provided by the disposable gown suggests that the disposable gown could be made lighter and still comply with AS3789.8. A lighter disposable gown would have reduced impacts from those determined in this study.

Other performance characteristics that are not directly addressed by the study were elements such as comfort, thermal properties, breathability and other elements. These characteristics were considered to be difficult to define and beyond the scope of study considered. Inclusion of these factors would be expected to affect the comparability of the gowns considered, so would be relevant in so much as they could alter what types of gowns that could be considered comparable. These other factors would not be expected to have significant environmental impacts, however.

3. Methodology

This study utilises LCA as a tool to evaluate the potential environmental impact of reusable and disposable surgical gowns over their lifetime. A description of the LCA process is provided in Appendix A.

Construction of the numerous process models associated with surgical gowns was heavily reliant on data provided by Textile Rental and Laundry Association and an anonymous survey of disposable gown manufacturers. In general process data associated with the laundry process (reusable gowns) was well understood and data provided was detailed in nature. Manufacturing data, however, was not readily available for the gowns and did not extend beyond basic manufacturing location and simple material composition.

3.1 Survey of disposable gown manufacturers

Disposable gown information was more difficult to collect. Concerns regarding the disclosure of intellectual property made it difficult for manufacturers to disclose detailed process data. For this reason an additional survey of manufacturers was conducted, in which 3 major manufacturers were asked to comment on the inventory and characterisation results associated with the disposable gowns. Responses to this survey were then used to refine the disposable gown analysis.

Manufacturers provided report feedback (pertaining just to the disposable gown aspects of the report), which was addressed in the report as described in Appendix B.

Other contributing process information, such as energy supply, water supply, transport and waste disposal were provided from reputable, publicly available sources where required (details described in Section 4).

3.2 Sima Pro®

The LCA comparison of the gowns was undertaken using the Sima Pro® software package to create life cycle models of each gown type which could then be analysed to determine various environmental impacts.

Sima Pro® is the most widely used Life Cycle Assessment software in the world. Introduced in 1990 in response to industry needs, the Sima Pro® product family facilitates the application of LCA using transparent analysis tools (process trees, graphs and inventory tables). Sima Pro® allows use of standard data provided and/or specific data to carry out environmental analysis and pinpoint where the main environmental priority areas are and look for possible improvements.

3.3 Assessment method

The impact assessment method used is based largely on the Leiden University – Institute of Environmental Sciences (CML) and EcoIndicator models. A list of factors used in the assessment method are published in 0.

Indicators used in this study are shown in Table 3-1.

Table 3-1: Environmental indicators

Indicators	Unit	Description
Global Warming	kg CO_2 eq	Climate change effects resulting from the emission of carbon dioxide (CO_2), methane or other global warming gases into the atmosphere – this indicator is represented in CO_2 equivalents. Factors applied to convert emissions of greenhouse gas emissions into CO_2 equivalents emissions conform to the Kyoto protocol of 1996.
Photochemical oxidation	kg C_2H_4 eq	Measurement of the increased potential of photochemical smog events due to the chemical reaction between sunlight and specific gases released into the atmosphere. These gases include nitrogen oxides (NOx), volatile organic compounds (VOCs), peroxyacyl nitrates (PANs), aldehydes and ozone. Factors applied to convert emissions into C_2H_4 equivalents are taken from the CML impact assessment method from 2000 (CML baseline 2000 all impact categories V2.04). CML is a research centre based in the Institute of Environmental Sciences of Leiden (the Netherlands).
Eutrophication	kg PO_4 eq	This is the release of nutrients (mainly phosphorous and nitrogen) into land and water systems, altering biota, and potentially increasing algal growth and related toxic effects. Factors applied to convert emissions into PO_4 equivalents are taken from the CML impact assessment method from 2000 (CML baseline 2000 all impact categories V2.04).
Carcinogens	DALY	Total damage caused by carcinogenic emissions measured in disability adjusted life years (DALY), a rate of mortality and morbidity that ranks years of life lost with years of disease and disability. Factors applied to convert emissions into DALY are taken from the Eco-Indicator impact assessment method from 1999 (Eco-indicator 1999 E V2.05). Eco-Indicator is an impact assessment method developed by PRe Consultant, a Dutch based research and consultancy company. The method has been developed between 1997 and 1999, commissioned by the Dutch Ministry of Urban Planning, Housing and the Environment.
Land use	Ha a (Hectare.years)	Total exclusive use of land for given time for occupation by the built environment, forestry production and agricultural production processes. Factors are based on CML impact assessment method from 2001 and reflect a simple summation of land.years occupied by the system being analysed.
Water use	kL H_2O	Net water use – potable, process, cooling. Water quality, water depletion, biodiversity. The indicator is a simple summation of water consumed by the system being analysed.
Solid waste	kg	Solid wastes from production and reprocessing. Impacts depend on character of waste. Mixture of final waste to landfill and production waste from the supply chain. This indicator has been designed according to the first CML impact assessment method (CML 92 V2.04). It reflects a simple summation of solid waste generated by the system being considered.
Minerals	MJ Surplus	The additional energy required to extract resources (both mineral and fossil) due to depletion of reserves, leaving lower quality reserves behind. The minerals indicator has been designed from an Eco-Indicator impact assessment method (Eco-indicator 1999 (H) V2.05). Eco-Indicator is an impact assessment method developed by PRe Consultant, a dutch based research and consultancy company. The method has been developped between 1997 and 1999, commissioned by the Dutch Ministry of Urban Planning, Housing and the Environment.

3.4 Allocation procedures

In general, allocation was avoided in the study by ensuring that unit processes were directly related to the production or processing of the products involved. This was particularly important within the laundry, which processes many items through similar processes (a multi input, multi-output process). Where direct metering was not possible within the laundry, energy consumption was estimated from first principles for the unit process under consideration, in preference to allocation. A check was then undertaken to ensure aggregate laundry impacts were reasonable (refer Section 4.2.11).

Allocation was required in this study to handle waste treatment processes and recycling processes. In general, system boundary expansion was used to handle recycling processes as discussed below. Waste treatment impacts were typically allocated on a mass or volume basis.

3.4.1 Treatment of recycling

Recycling is not considered in the base case analysis, however is considered in a sensitivity study associated with disposal of the disposable gown at end of life (Section 7.4). In this sensitivity, recycling is handled using system expansion as shown in Figure 3-1.

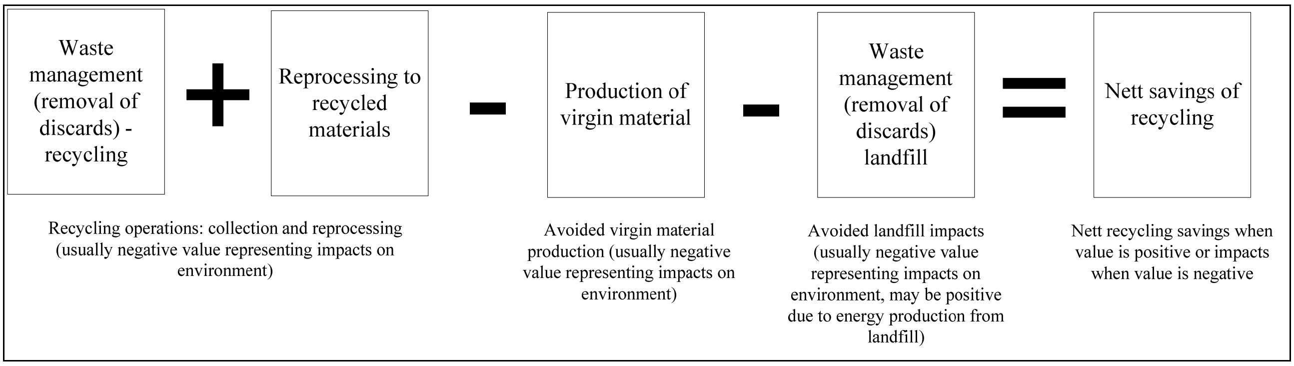

Figure 3-1 Treatment of recycling.

Process data for recycling and avoided products is taken from (Grant, James et al. 2001).

3.4.2 Treatment of reuse

Garment reuse in the case of the reusable gown and huck towel, was handled by considering the total impacts associated with manufacture of the gown and huck towel and dividing these by the total number of expected uses. These were then allocated to a single use of the gown. Other impacts associated with reuse such as laundering and transport were discernable for each use so did not require specific allocation procedures.

4. Life Cycle Inventory

The following inventory documents the major process flows within the system boundary (refer Section 2.3) of the life cycle of a reusable and disposable surgical gown.

4.1 Data quality

A data quality assessment was undertaken for both the disposable and reusable systems assessed.

Data quality has been assessed as described by ISO 14044. A summary of assessment results is shown Table 4-1.

Table 4-1 Data quality assessment.

	Timeframe	Geography	Technology	Precision	Completeness	Representativeness	Concistency	Reproducibility
	Year	Country of majority data			% measured	Poor/Medium/ Good	Poor/Medium/Good	Poor/Medium/Good
Reusable gown								
Gown manufacture	1996-2007	Cotton: China/Europe Polyester: Europe	Unknown	Unknown	50%	Medium	Medium	Medium
Laundry process	2000-2008	Australia	Better than average	Unknown	80%	Medium	Good	Good
Transport	2000-2008	Australia	Industry average	Unknown	80%	Good	Good	Medium
Waste treatment	2000-2005	Australia	Industry average	Unknown	50%	Good	Good	Medium
Disposable gown								
Gown manufacture	1999-2008	Europe/USA	Mix	Unknown	30-90%	Good	Mix	Mix
Polypropylene granulate	1999	Europe	Industry average	Unknown	90%	Good	Good	Medium
Spunweave provess	2008	USA	Unknown	Unknown	30%	Poor	Medium	Poor
Waste treatment	2000-2005	Australia	Industry average	Unknown	50%	Good	Good	Medium

Data quality achieved in the study is variable and differs between reusable and disposable gowns. In general, a higher standard of completeness, consistency and reproducibility was achieved for the reusable gown processes, because these were readily accessible and information was freely available. Processes associated with disposable gowns tended to be more difficult to access, possibly due to confidentiality issues as well as the remote nature of manufacturing processes (many overseas). Hence, disposable gown data tended to be less complete.

The reusable gown data collected in the 'base case' analysed in this study, probably reflects laundry processes that are better than average in terms of their execution. Water recycling was considered to be standard as well as wastewater heat recovery. To address the possibility that the laundry data were not reflective of the industry as a whole, a sensitivity study was undertaken that removed water recycling and heat recovery from the laundry processes, and is discussed in Section 7.2.

Overall, the data quality achieved are believed to be sufficient to judge the scale of impacts under each gown system, and to determine preference with respect to environmental impacts. In areas of uncertainty, sensitivity analysis has been used to test study conclusions (refer Section 7).

4.1.1 Further work

An area where further data refinement could be undertaken is in the area of fabric production associated with disposable gowns. Analysis used in this study is based on broad data collected from the industry and a generic polypropylene feedstock inventory (developed by Plastics Europe) was used. This dataset could be further refined by undertaking a detailed study of the manufacturing processes associated with the fabric. Although confidentiality could be a challenge in such a study, it is believed that such issues could be easily overcome.

4.2 Reusable gown and huck towel pack

The reusable pack inventory is based on the process diagram described in Figure 2-1. In determining the inventory for the reusable pack, the following process information was incorporated, the bulk of which was collected with the help of the Textile Rental and Laundry Association (TRLA). The data is based largely on a single facility.

4.2.1 Components of a reusable surgical pack

The reusable surgical pack, when delivered to the hospital for use contains the components shown in Table 4-2.

Table 4-2 Components of reusable surgical pack.

Component	**Mass**
Gown	287g
Huck towel	73.5g
Autoclave indicator tape	5g
Non-woven wrap	12.8g
Dustcover	14.9g
Total	**393.7g**

4.2.2 Manufacturing of gown and huck towel

The reusable gown is made from a polyester blend fabric which is manufactured in China, then assembled into a gown in Melbourne, Australia. The manufacturing process for the fabric was not known, a model was developed based on existing studies of polyester and cotton fabric manufacture (Laursen, Hansen et al. 1997). Assembly impacts in Melbourne were estimated based on energy required to cut and sew a gown.

Gown life and weight were important parameters in this LCA study and were provided by the gown manufacturer and a local laundry (member of TRLA) respectively.

Transportation distances were based on known shipping distances and utilised generic transport models. All truck transportation has been modelled on average industry practice in Australia and incorporates a backhaul ratio of 1.2 (80% of return trips are empty).

The key inventory assumptions developed for the manufacture of the reusable gown are shown in Table 4-3.

Table 4-3 Reusable gown inventory assumptions and sources.

Reusable surgical gown at laundry							**Source***
	Material:		Blend: Cotton 6%/Polyester 94%				E-Tex
			6% Cotton fabric manufacture:				
			Process based on China/Eastern Europe				Ecoinvent
			94% Polyester fabric manufacture:				
			Polyester based on European data				EcoInvent
			modifed for Coal fired electrcity (Australia				Aus Data
			used as proxy).				
			Fabric manufacture based on Laursen				Laursen
			using coal fired electricity (Aus as above)				Aus Data
			Fabric performance:				
			Compliant with AS 3789.8				
			(Liquid penetration at 3.0kPa,30.51cmH2O)				
	Fabric location:		Xiemen, China				E-Tex
	Gown location:		Thomastown, Victoria				E-Tex
	Gown manufacture:		Not known: assume minimal impact				Estimate
	Mass:		0.287	kg/pack			Weighed
	Lifetime of gown:		127	washes			Laundry
	Transport:						
		Xiemen, China to port:		Rigid truck		100km	Estimate
		Port to Melbourne:		Ship		9617km	Estimate
		Port to manufacture:		Rigid truck		30km	Estimate
		Maunfacture to Laundry:		Rigid truck		30km	Estimate

* Sources listed in Section 11.

The reusable huck towel was assumed to be made from 100% cotton fabric, although no specific manufacturing data was available. The cotton fabric manufacturing process was based on an Ecoinvent database model.

Gown life is based on inventory replenishment rates and annual inventory turns. The calculation that determines gown life is based on data provided by the laundry and is summarised in Table 4-4. Gown life accounts for all losses from the returnable system, irrespective of cause.

Table 4-4 Determination of gown life.

Col	Name	Amount	Unit
Data provided			
	Gowns processed	2,950	Gowns per week
a	Gowns processed	153,400	Gowns per annum
b	Inventory (in circulation)	4,425	Gowns
	Replacement rate	100	Gowns per month
c	Replacement rate	1,200	Gowns per annum
Calculations			
d	Inventory turns (a/b)	34.7	turns p.a.
e	Gown life (b/c) - years	3.7	years
	Gown life (d*e) - cycles	127.8	cycles

The key inventory assumptions developed for the manufacture of the reusable huck towel are shown in Table 4-5. Huck towel life was not known at the time of report writing and has been assumed to be similar to that of the gown (127 cycles).

Table 4-5 Reusable huck towel inventory assumptions and sources.

Reusable huck towel at laundry							**Source***
	Material:		Cotton fabric manufacture:				
			Process based on European data				Ecoinvent
	Location:		Xiemen, China				Estimate
	Mass:		0.074	kg/pack			Weighed
	Lifetime of towel:		127	washes			Laundry
	Transport:						
		Xiemen, China to port:		Rigid truck		100km	Estimate
		China to Melbourne:		Ship		9617km	Estimate
		Port to Distribution:		Rigid truck		30km	Estimate
		Distribution to Laundry:		Rigid truck		30km	Estimate

4.2.2.1. Treatment of reuse – manufacturing impacts per cycle

Environmental flows associated with reusable items (gown and huck towel) have been determined by dividing the inventory of flows associated with manufacturing and disposing of the items by the expected life of the items. In this case, both gown and huck towel inventories are divided by the expected life of 127 cycles, to give environmental flows per cycle.

4.2.3 Check in and separation

The check in and separation process involves a labour intensive task of sorting incoming dirty garments when they enter the laundry. The process was considered to contribute minimally to the overall environmental impact, however some solid waste was generated in the form of waste tape (autoclave tape) which was disposed of to landfill.

4.2.4 Extractor wash process

The extractor wash process modelled was based on a wash cycle of a 100kg capacity Milnor washing machine. The machine accepts a mix of cold and hot water over a 1 hour cycle (80% hot water at 80 degrees C), using a total of 22 litres per kg of soiled fabric washed.

Wash water is heated by a boiler running on natural gas which is assumed to be 75% efficient. Water is assumed to enter the boiler at 15 degrees C and exit at 80 degrees C. Heating energy and the resultant fuel requirements have been estimated based on the efficiency of the boiler and the specific heat of water (refer Equation 1).

Equation 1 Boiler energy requirements.

$$q_{\text{boiler}} = \frac{mC_p(T_{\text{out}} - T_{\text{in}})}{\chi}$$

where:

q_{boiler} = heat required from fuel (gas) at boiler

m = mass of water heated

C_p = specific heat of water

$T_{\text{out}} - T_{\text{in}}$ = change in temperature of water

χ = efficiency of boiler

Water is partly supplied by potable mains supply (60%) and partly by a heat and water recycling system (Figure 4-1). The recycling system treats waste rinse water within the laundry and returns the water for use in pre-wash and main rinse stages. The recycling system fitted at the laundry also reduces heating energy used during the wash cycle by 15%, by supplying already warm water from the previous wash.

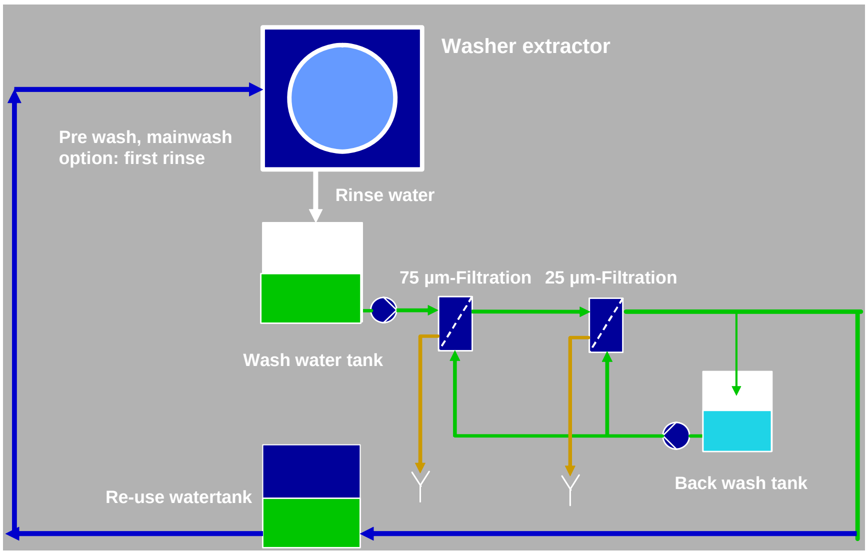

Figure 4-1 Recycling schematic layout (Ecolabs 2007).

Potable water supplied is assumed to come from a typical Melbourne water supplier. Impacts associated with water supply are based on work previously undertaken by the Centre for Design in the water supply area.

The chemical breakdown of the detergent used in the wash process was supplied by Ecolabs, who supply the detergent to the laundry.

The key inventory assumptions developed are shown in Table 4-6.

Table 4-6 Extractor wash inventory assumptions and sources.

Extractor wash process							**Source***
	Machine type:		Milnor				Laundry
	Water heated to:		80	deg C			Laundry
	Heat from natural gas:		1.95	MJ/pack			Estimate
			5.42	MJ/kg(dry fabric)			
			Hot water proportion	*80%*			Estimate
			Specific heat water	*4.179*	*kJ/kg(water)/K*		
		15deg to 80deg	*q=*	*271.635*	*kJ/l(water)*		
			Efficiency of boiler	*75%*	*(average perfomance)*		Estimate
			Aquamiser benefit	*15%*			Ecolab
	Electricity:		0.018	kWh/pack			
			0.05	kWh/kg(dry fabric)			
			Consumption	*5*	*kW motor*		Compliance plate
			Capacity	*100*	*kg*		Laundry
			Operation	*1*	*hr*		Laundry
	Total water:		7.94	l/pack wash water			
			4.76	l/pack waste water			
			22	l/kg(dry fabric)			Laundry
			Recycle rate	*40%*			Ecolab
			Potable water	*13.2*	*l/kg*		AusData 2007
			Recycled water	*8.8*	*l/kg*		
	Wash chemicals:		0.006	l/pack			
			0.018	l/kg(dry fabric)			Ecolab data
				Refer Appendix E for detergent chemistry			
				and phosphorous content.			

4.2.5 Drying

Drying energy was not directly measurable from the gas fired Kamsen drying machine. Drying energy is highly dependent on the type of fabric being dried, the water content, the distribution of moisture, the efficiency of the machine, the temperature of the fabric and other factors. The drying energy consumption used in this study is based on the average consumption for the Warragul Linen Service laundry (Warren 2007). This result was compared to published performance specifications of a commercial grade gas fired tumble dryer (Electrolux 2007) and a published domestic dryer study (Yadav and Moon 2008) and found to lie in between these comparisons.

Table 4-7 Dryer energy requirements per kg of fabric (dry).

Information source	Test Type	kWh per kg to dry fabric
Yadav and Moon (2008)	Domestic electric dryer. Cotton sheets.	1.25

	47% water dried to 3%.	
Electrolux (2007)	Commercial gas dryer. At rated capacity 100% cotton load at 50% initial moisture dried to 0%.	0.59*
Warren (2007)	Average gas consumption for drying at Warragul Linen Service	0.87*

* Converted from MJ natural gas consumption.

The variability of energy requirements shown in Table 4-7 reflects the significant influence of the many parameters that affect drying energy use. The Warren data was selected as it represents a mid-point of studies considered and is based on known local laundry performance. It is also likely that commercial scale laundry machines drying polyester blend fabric would use less energy than the domestic scale machines drying cotton fabrics that were used in the Yadav and Moon study.

Tumble dryer rotational energy was estimated separately according to the compliance plate on the machine and typical drying time.

The key inventory assumptions developed are shown in Table 4-8.

Table 4-8 Dryer inventory assumptions and sources.

	Machine type:		Kamsen				
	Heat from natural gas:		1.1300256	MJ/pack			
			3.132	MJ/kg(dry fabric)			
			Fabric weight	*Assume similar to cotton*			Estimate
			Moisture content	*50%*			Estimate
			Estimated drying energy	*0.87*	*kWh/kg*		Warren (2007)
	Electricity:		0.018	kWh/pack			
			0.05	kWh/kg(dry fabric)			Estimate
			Consumption	*5*	*kW motor*		Compliance plate
			Capacity	*100*	*kg*		Compliance plate
			Operation	*1*	*hr*		Laundry

4.2.6 Inspection and folding

The inspection and folding stage of laundry operation was assumed to involve no significant environmental impacts, however can result in garments being destroyed when they are deemed to be at the end of their life. The solid waste impact of this is included in the LCA, which assumes that reusable gowns go to landfill at the end of their useful lives.

4.2.7 Complete and wrap

The complete and wrap stage involves adding a polypropylene non-woven wrap to the gown and huck towel pack and the addition of autoclave sterilisation indicator tape. The nonwoven wrap is assumed to be made of the same non-woven polypropylene fabric that the disposable gowns used in this study are made from (refer 4.3.2).

Little is understood about exactly how this fabric is manufactured, however good information exists as to how the primary constituent, polypropylene, is manufactured. An estimate of fabric manufacture was developed based on a model of polypropylene granulate manufacture in Europe developed as part of the Ecoinvent database, combined with spinning energy and water use information collected as part of the disposable gown manufacturer survey (refer Table 4-17).

Indicator tape applied is small in quantity relative to the mass of the gown and huck towel pack, and is assumed to be made from kraft paper. The purpose of the tape is to provide visual confirmation that the packs have been sterilised through the autoclave process.

The key inventory assumptions developed are shown in Table 4-9.

Table 4-9 Complete and wrap inventory assumptions and sources.

	Tape added:		0.005	kg/pack	Paper tape		Laundry
		Material:	Assume kraft process or similar				AusData 2007
	Non-woven wrap added:		0.0128	kg/pack			Laundry
		Material:	Polypropylene non woven fabric				Refer 'Disposable
							Gown'
Autoclave							**Source***

4.2.8 Autoclave (sterilisation)

The autoclave process sterilises the packs in accordance with AS4187 (Standards Australia 1998). Sterilisation is undertaken using a Getinge steam autoclave that ensures that packs achieve 134 degrees C for 3.5 minutes. The machine's primary requirements are steam to achieve the temperature required as well as some electricity to achieve vacuum levels that are also required as part of the cycle.

Energy usage was estimated based on the change in enthalpy involved to take saturated water at room temperature and pressure to saturated steam at 220kPa (Van Wylen and Sontag 1985) and the required operating pressure of the autoclave. Steam is supplied by the laundry boiler which is powered by natural gas and is assumed to have an efficiency of 75%. Steam quantities used per hour were supplied by Getinge (2007).

The key inventory assumptions developed are shown in Table 4-10.

Table 4-10 Autoclave inventory assumptions and sources.

	Machine type:		Getinge				
	Heat from natural gas:		0.654	MJ/pack			
			1.813	MJ/kg(dry fabric)			
			Steam requirement	*40*	*kg/hr (avg)*		Getinge
			Water	*1259*	*kg/hr (avg)*		Getinge
			Capacity	*80*	*kg/hr (avg)*		Getinge
			Operating time	*1*	*hr*		Getinge
			Vacuum	*-90*	*kPa*		Getinge
			Heat	*134*	*Deg C*		Getinge
			Time at temp	*3.5*	*mins*		Getinge
			Start pressure	*101.325*	*kPa*		Estimate
			Heated pressure	*220*	*kPa*		Getinge
			Start enthalpy	*83.96*	*kJ/kg (sat liquid)*		Van Wylen et al.
			Heated enthalpy	*2803*	*kJ/kg (sat vapour)*		Van Wylen et al.
			Boiler efficiency	*75%*			Estimate
			Heat from gas required	*3625.3867*	*kJ/kg (steam)*		
			Heat from gas required	*145.01547*	*MJ/hr*		
	Electricity:						
			0.025	kWh/kg(dry fabric)			
			Electrcity consumption	*2*	*kW(avg)*		Getinge

4.2.9 Cool down

Following the autoclave process, the surgical packs are cooled in a cool down room. The cool down room consists of an air conditioned area, where the packs soak until they return to 22 degrees C from 134 degrees C (post autoclave).

The energy requirements of the cool down room are primarily associated with operation of the air conditioner in this area which is assumed to be of moderate efficiency (Coefficient of Performance of 2.0). Energy requirements are estimated based on the specific heat of polyester.

The key inventory assumptions developed are shown in Table 4-11.

Table 4-11 Cool down room inventory assumptions and sources.

	Air conditioner:		0.007	kWh/pack			Estimate
			0.019	kWh/kg(dry fabric)			Estimate
			Specific heat polyester	*1200*	*J/kg/K*		
			Start temp	*134*	*Deg C*		
			End temp	*22*	*Deg C*		
			Cooling energy required	*134.4*	*kJ/kg(dry fabric)*		
			COP	*2*			
			q=	*67.2*	*kJ/kg(dry fabric)*		
				0.019	*kWh/kg(dry fabirc)*		

4.2.10 Add dust cover

A plastic dustcover is added to the packs once they have cooled which is made from high density polyethylene (HDPE). Manufacturing data for HDPE was not available however a generic model of the process was available in the Ecoinvent database that was based on European manufacturing data.

The key inventory assumptions developed are shown in Table 4-12.

Table 4-12 Addition of dustcover inventory assumptions and sources.

	HDPE bag added		0.0149	kg/pack			
		Material:	High density polyethylene				Ecoinvent

4.2.11 Aggregated energy use within the laundry facility

The processes described in Sections 4.2.3 to 4.2.10 that take place within the laundry all consume energy and water. To check the estimates of energy consumption and water consumption across these processes, they were totalled and compared to the aggregate energy consumption of the laundry facility itself (based on meter readings over a year). The results are shown in Table 4-13.

Table 4-13 Comparison of calculated energy use to actual energy use for laundry facility.

		Plant aggregate	Total of calculated amounts**
Gas*	MJ	7.09	10.36
Electricity	kWh	0.15	0.14
Water	l	11.11	13.20

*Gas total based on Braeside Plant due to data collection problems; other totals based on Warragul plant
** Includes recycling benefits for water and gas.

Overall, the theoretical energy and water consumption estimates correlated reasonably well with actual energy and water consumption across the facilities considered. A possible reason for the higher calculated gas usage versus aggregate, could be fact that most laundered products do not pass through the autoclave process, thereby reducing overall facility consumption.

4.2.12 Trucking and Usage

Once laundered and sterilised the packs are supplied to hospitals. A key assumption of this study was that hospitals are, on average, 50km from the laundry.

Trucking is undertaken by a rigid truck, the model for which has been developed as part of the Australian Database 2007. The model uses average fuel consumption and emissions based on Australian data, and incorporates a backhaul ratio of 1.2 (assumes trucks are empty on return journey 80% of the time).

Transport is assumed to take place from the laundry to the hospital in one leg, and from the hospital to the laundry once the gowns are soiled.

Usage impacts are assumed to be negligible, however waste is assumed to be generated as disposable components of the surgical packs are removed and disposed of (such as the dust cover and non-woven wrap). Details regarding solid waste disposal are describe in Section 4.2.13.

The key inventory assumptions developed are shown in Table 4-14.

Table 4-14 Trucking and usage inventory assumptions and sources.

	Laundry to hospital:						
		Rigid truck	50	km			Estimate
Use							**Source***
	HDPE bag disposed of to landfill						
	Non-woven wrap disposed of to landfill						
		Landfill model based on Australian experience					AusData 2007
Truck to laundry							**Source***
	Location						
			50	km radius			

4.2.13 Waste disposal

Both liquid waste and solid waste are generated over the life cycle of the reusable pack.

<u>Liquid waste</u>

Liquid waste is generated through the wash process in the form of contaminated water from the extractor washing machines. This water is partly treated for reuse by the recycling system (refer Section 4.2.4) and partly disposed of to the sewer (with some minor pH buffering).

It is assumed that the sewerage flow from the laundry would contain an above average flow of nutrients. Nutrient content has been estimated based on the nutrient content of the detergent used and the nutrients assumed to be present in the soiling of the gown. A soiling rate equivalent to 0.5 litres of abattoir wastewater per gown and towel (combined) has been assumed for this study. For further information regarding the treatment of nutrients in this study, refer to Appendix E.

Once entering the sewer, the liquid waste is assumed to be transported to the Eastern Treatment Plant, in Melbourne, where it is treated then disposed of to the ocean. In this study the energy required to transport the waste through the sewer system and the energy to treat sewerage is assumed to be similar to that associated with the disposal of domestic sewerage in Melbourne. The LCA model developed for sewerage treatment is based on local Melbourne experience (Grant. T. & Opray. L. 2005).

Retention of nutrients by the sewerage treatment plant is assumed to be consistent with ratios published by Melbourne Water for the Eastern Treatment Plant (Melbourne Water. 2005). Refer to Appendix E for details regarding retention rates assumed.

The key inventory assumptions developed for liquid waste treatment are shown in Table 4-15.

Table 4-15 Emissions and energy requirements associated with liquid waste treatment from laundry.

Energy required to pump and treat sewerage			
Electricity	1.507 kWh/kL		Grant(2005)
Emissions from Wastewater Treatment Plant to Ocean per kL of sewerage treated			
BOD5, Biological Oxygen Demand*	52	g	Melbourne Water(2005)
Suspended solids, unspecified**	38	g	Melbourne Water(2005)
Ecoli organisms	70000	organisms	Melbourne Water(2005)
Nitrogen	6.3	g	Calculated - Appendix E
Phosphorous	5.6	g	Calculated - Appendix E

* BOD emission from Melbourne Water (2005) assumes treatment by municipal wastewater treatment plant prior to waste flow to environment. Actual emission to sewer by laundry facility equal to 83g per kilolitre (Warren 2007)
** TSS emission from Melbourne Water (2005) assumes treatment by municipal wastewater treatment plant prior to waste flow to environment. Actual emission to sewer by laundry facility equal to 115g per kilolitre (Warren 2007)

Table 4-15 describes emissions and energy requirements associated with municipal wastewater treatment assumed in this study. The results shown assume that the wastewater treatment plant is able to remove BOD, suspended solids, phosphorous and nitrogen to those levels shown in the table above.

<u>Solid waste</u>

Solid waste generated through the use of reusable packs is associated with the disposal of the non-woven wrap, dustcover, autoclave indicator tape and gowns (after 127 washes). This waste is assumed to be inert in nature and is assumed to be disposed of to municipal landfill.

An Australian Database 2007 model for inert waste in municipal landfill was used to model this waste, incorporating collection and processing of the waste stream. This model was developed as through various waste studies undertaken by the Centre for Design at RMIT.

4.3 Disposable gown and huck towel pack

The disposable gown inventory contains many similar elements to the reusable gown, however the life cycle is simpler as there is no reuse phase involved.

- Manufacturing of gown and huck towel
- Assembly of pack
- Use

- Waste disposal
- Transportation (embedded above)

The following inventory was compiled using data collected from a surgical gown and huck towel pack sold into hospitals locally in Melbourne, and by using data supplied by manufacturers via survey. Data gaps were filled by using existing published research and estimates where necessary.

The processes considered above exclude a sterilisation phase, unlike the reusable gown, which must go through an autoclave process. Some comment was received from the survey of disposable manufacturers that suggests that a sterilisation process does in fact occur for reusable gowns, however without sufficient evidence it was decided that it should be excluded. This is not to suggest that the disposable gowns are not sterile, rather that it is assumed that they can be produced in a sterile environment. Addition of a sterilisation phase would increase the environmental impacts associated with a disposable gown.

4.3.1 Components of disposable surgical pack.

The disposable surgical pack analysed contains the components shown in Table 4-16 when delivered to the hospital (any merchandising or traded packaging is excluded from the list due to lack of information). The following information was compiled through the analysis of a surgical gown pack considered to be equivalent to a reusable gown back (as judged by the disposable gown manufacturer).

Table 4-16 Components of disposable surgical pack.

Component	**Mass**
Gown	222g
Huck towel	13.9g
Non-woven Wrap	12.8g
Dustcover	21.9g
Total	**270.6g**

4.3.2 Manufacturing of gown and huck towel

The disposable gown is assumed to be made from a non-woven polypropylene fabric which is manufactured in the USA (assume New York, exact location unknown) and assembled into a gown in La Ceiba, Honduras (Honduras indicated on gown packaging reviewed in this study). The manufacturing process for the fabric was not known, so a proxy model was developed based on generic models for polypropylene granulate manufacture and survey feedback suggesting typical energy and water requirements for the spinning process. Gown assembly impacts were assumed to be similar to those assumed for the reusable gown.

Transportation distances were based on known shipping distances and utilise generic transport models. All truck transportation has been modelled on average industry practice in Australia and incorporates a backhaul ratio of 1.2 (80% of return trips are empty).

The key inventory assumptions developed for the disposable gown are shown in Table 4-17.

Table 4-17 Disposable gown inventory assumptions and sources.

Disposable surgical gown at La Ceiba centre							**Source***	
	Material:		Manufacturing process for polypropylene					
			based on European manufacturing process.				Ecoinvent	
							(based on	
							Plastics Europe	
							ecoprofile)	
	Processing:		Fabric manufacture					
		Elec. (USA)	10.0	MJ/kg fabric			Survey feedback	
		Water	1	l/kg fabric			Survey feedback	
	Fabric location:		USA - assume New York				Estimate based on	
							survey feedback.	
	Assembly location:		Honduras - assume La Ceiba				Based on gown packaging	
	Mass:		0.222	kg/pack			Weighed	
	Lifetime of gown:		1	use				
	Transport:							
		New york to La Ceiba		Ship		3165km	Estimate	

The huck towel supplied with the disposable pack is made from paper, however detailed manufacturing data was not available. The manufacturing process is assumed to be similar to paper manufacture in Sweden through a typical European Kraft process. The model used is taken from the Ecoinvent database. This model assumes a high level of paper process technology.

The key inventory assumptions developed for the disposable huck towel are shown in Table 4-18.

Table 4-18 Disposable huck towel inventory assumptions and sources.

Disposable clinical towels at La Ceiba							**Source***	
	Material:		Paper fibre hand towel x1				Ecoinvent	
	Location:	Assume manufactured in Stockholm, Sweden					Estimate (location unknown)	
	Mass:	0.0139	kg				Weighed	
	Lifetime of towel:		1	use				
	Transport:							

4.3.3 Assembly of pack

It was assumed that the gown, huck towel and non-woven wrap were assembled into a pack at a local distribution centre in La Ceiba, Honduras, then shipped to Melbourne, Australia.

The dustcover used in the disposable design is a composite type which is partly made from paper and partly from HDPE (materials assumed based on inspection). Non-woven polypropylene wrap manufacturing data were not available so were assumed to be a similar the non-woven polypropylene fabric to that is used to manufacture the disposable gown. Sources are shown below in Table 4-19.

Table 4-19 Assembly inventory assumptions and sources.

Assemble pack in La Ceiba, ship to Melbourne							**Source***
	Dust cover added		0.0219	kg			Weighed
		Material:	50% HDPE				Ecoinvent
			50% Bleached kraft paper				Ecoinvent
	Wrap		0.0128	kg	(0.63mx0.63m)		
		Material:	Wrap (assume polypropylene				As per gown above
			nonwoven)				
	Transport:						
		La Ceiba to Melbourne		Ship		18757km	Estimate
		Port to Distribution		Rigid truck		30km	Estimate

4.3.4 Usage and distribution

Trucking is undertaken by a rigid truck from the distribution centre to the hospital over an assumed distance of 50km. The model used in the LCA study has been developed as part of the Australian Database 2007. The model uses average fuel consumption and emissions based on Australian data, and incorporates a backhaul ratio of 1.2.

The key inventory assumptions developed are shown in Table 4-20.

Table 4-20 Usage and distribution inventory assumptions and sources.

Truck to hospital							**Source***
	Laundry to hospital:						
		Rigid truck	50	km			Estimate
Use							
	Gown and huck towel disposed of to landfill.						

Usage impacts associated with the gown are assumed to be negligible.

4.3.5 Waste disposal

Waste generated by the disposable packs is primarily associated with the disposal of the pack components after the use phase. The components are assumed to go directly to landfill and are assumed to be inert.

In some instances, it is recognised that contaminated gowns may be classified as medical waste and therefore incinerated as part of Environmental Protection Act guidelines. Incineration was handled in this study as a sensitivity analysis in Section 7.

An Australian Database 2007 model for inert waste in municipal landfill was used to model this waste, incorporating collection and processing of the waste stream.

5. Results

LCA results were calculated over the life of disposable and reusable surgical gown packs. Results have been presented per functional unit, which in this case represents the single use of a sterile surgical pack.

Results have been presented in two forms: i) a characterised results, and ii) normalised results.

5.1 Results Characterisation

The Life Cycle Characterisation applies the Assessment Method (refer Section 3.3) to the inventory developed in order to determine potential environmental impacts per use. All impacts identified in the Life Cycle Inventory (Section 4) are added and interpreted using the Assessment Method to give the impact per surgical pack use.

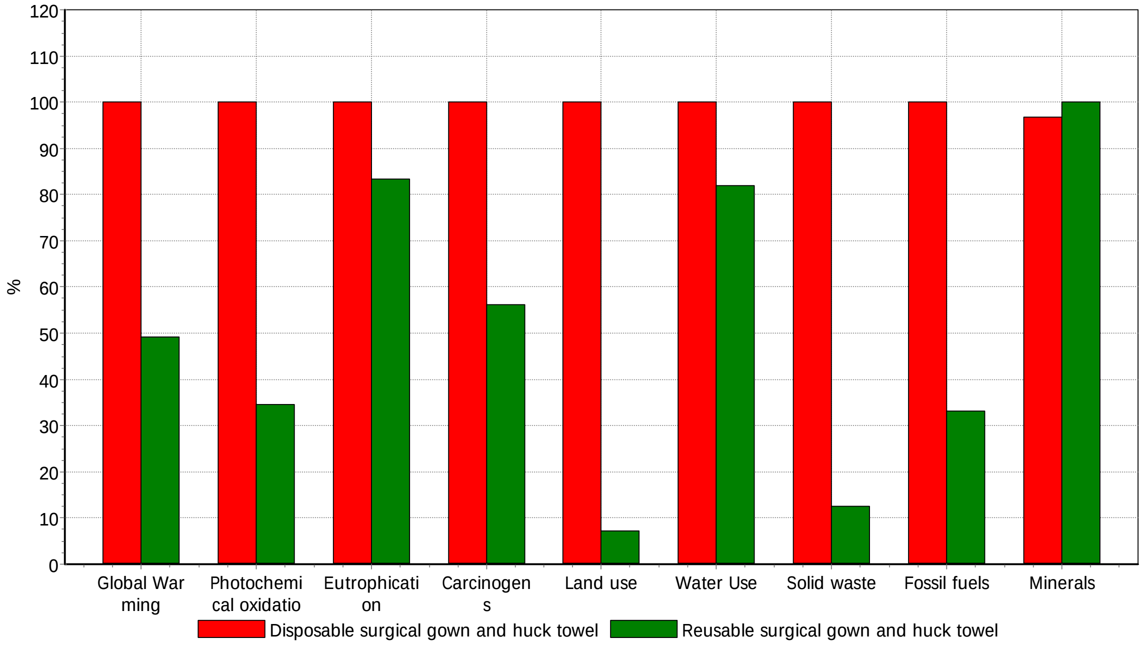

Figure 5-1 Comparison of life cycle impacts of disposable versus reusable surgical packs.

Table 5-1 Characterisation of life cycle impacts per surgical pack use.

Impact category	Unit	Disposable pack	Reusable pack
Global Warming	kg CO2	1.0E+00	5.1E-01
Photochemical oxidation	kg C2H4	4.6E-04	1.6E-04
Eutrophication	kg PO4--- eq	5.5E-04	4.6E-04
Carcinogens	DALY	1.3E-08	7.6E-09
Land use	Ha a	2.4E-05	1.7E-06
Water Use	KL H2O	1.4E-02	1.1E-02
Solid waste	kg	3.4E-01	4.3E-02
Fossil fuels	MJ surplus	1.9E+00	6.4E-01
Minerals	MJ Surplus	1.0E-03	1.1E-03

5.2 Results Characterisation – 'Equivalent units'[2]

In order to facilitate the interpretation of the characterised results described in Section 5.1, they were restated in terms of commonly understood activities, as shown in Table 5-2. The translation of the characterisation results was undertaken using factors and sources described in the supporting Table 5-3.

Table 5-2 Characterised results shown in equivalent units.

Impact category	Factor*	Unit	Disposable pack	Reusable pack
Global Warming	20	Ballons	20.6	10.1
Photochemical oxidation	1255511	m car travel	572.5	198.0
Eutrophication	80283	litres grey water	44.5	37.1
Carcinogens	76	kg arsenic	0.000001	0.000001
Land use	0.5	Footy fields	0.000012	0.000001
Water Use	100	buckets	1.4	1.1
Solid waste	1	kg waste	0.34	0.04
Fossil fuels	0.007	household energy days	0.014	0.005
Minerals	0.007	household energy days	0.00001	0.00001

* Factors shown were developed from sources as described in Table 5-3.

Table 5-3 Factors and sources used to create equivalent units shown.

Indicator	Amount	Unit	Source
Global warming	20	Balloons / kg CO2	Based on 50g per black balloon, www.saveenergy.vic.gov.au
Photochemical smog	1255511	m car travel / kg C2H2	Based on Australian Greenhouse Office (2002), 'National Greenhouse Gas Inventory 2000', Canberra, Australian Greenhouse Office. Assumes 4.1MJ per km energy consumption for passenger car transport.
Eutrophication	80283	L grey water / kg PO4--- eq	Calculation based on the typical P content of household laundry grey water (Total P 3.46mg/L). Source: Sharma,A.,Grant, A., Gray, S., Mitchell, G.(2005),'Sustainability of Alternative Water and Sewerage Servicing Options', CSIRO Urban Water & Centre for Design at RMIT
Carcinogens	76	kg Arsenic / DALY	Based on equivalent toxicity of Arsenic released to soil (1.32E-2 DALY). Source: Ecoindicator 99 Impact Assessment Method
Land use	0.5	Footy fields / Ha a	Number of MCG football areas (20290m2, 2.029Ha a) taken up by activities such as farming, power generation facilities) source: www.mcg.org.au
Water use	100	10l Buckets / KL H2O	Based on typical household bucket volume of 10litres.
Solid waste	1	kg rubbish / kg	Simple unit of mass.
Fossil fuels	0.007	House E days / MJ surplus	Unit based on daily household energy use of 51.4GJ/household p.a. average Source: Wilkenfeld, G., (1998), Household Energy Use in Australia,www.energyrating.gov.au
Minerals	0.007	House E days / MJ surplus	Unit based on daily household energy use of 51.4GJ/household p.a. average Source: Wilkenfeld, G., (1998), Household Energy Use in Australia,www.energyrating.gov.au

5.3 Normalised results

Normalised results alter the characterisation results to give an indication of the relative significance of the indicators to each other. Comparison of indicators with quite different units of measure is achieved by dividing the characterisation results by the per-capita environmental impact of an average Australian. The normalised results should not be interpreted as describing which indicators are most important, rather they should be viewed as describing environmental impacts relative to a known baseline impact (good bad or indifferent).

[2] Note: This section was added subsequent to completion of the peer review. It has therefore not been 'peer reviewed'.

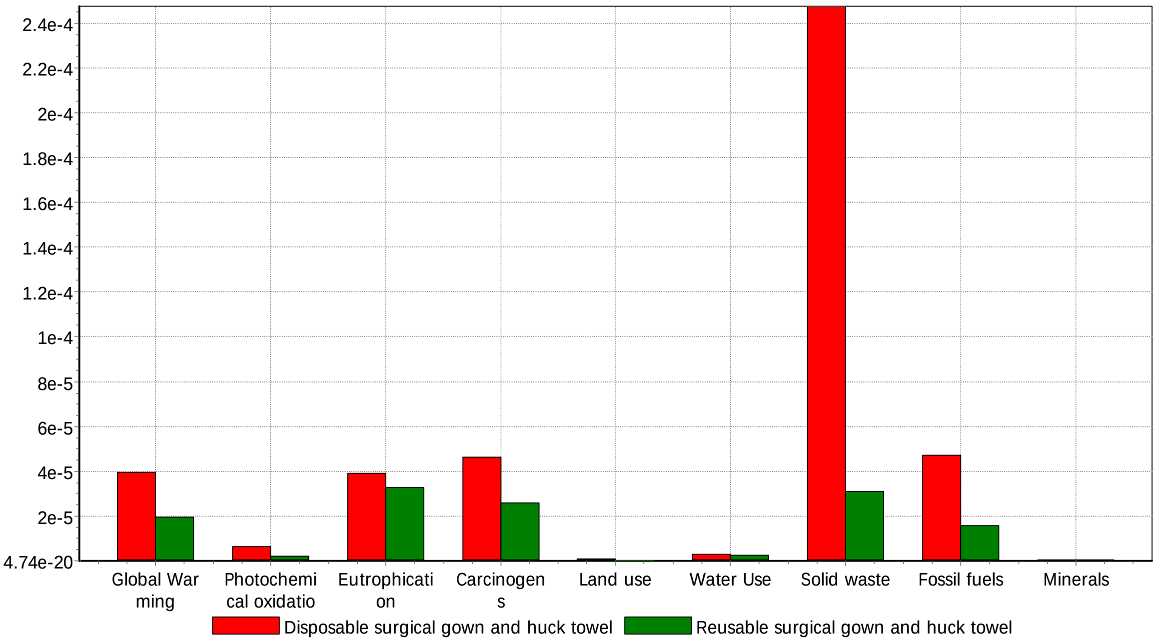

Figure 5-2 Comparison of life cycle impacts of disposable versus reusable surgical packs (normalised results - Australian per capita).

6. Discussion

Significant differences were found to exist between the potential environmental impacts of disposable and reusable surgical packs over their lifetimes. Generally, impacts appeared to be higher for disposable packs in most indicators, with the exception of the minerals indicator.

The normalised results suggest that land use impacts, water use and mineral impacts were relatively small for both reusable and disposable surgical packs. This may, in turn, suggest that results in these indicators could be of lesser significance in an Australian context.

6.1 Drivers of environmental impact – Reusable surgical packs

Figure 6-1 identifies those processes that contribute to the impacts described by each indicator for reusable surgical packs. The diagram illustrates the significant contribution of the extractor wash process to most indicators, followed by contributions associated with the drying and autoclave processes. These processes have larger impacts because they are energy intensive, however the extractor wash process also consumes significant quantities of water and chemicals, and generates phosphate laden liquid waste.

Other processes also contribute to impacts to a lesser degree. The disposable non-woven wrap and dust cover also contribute to most indicators, and drive the solid waste outcome.

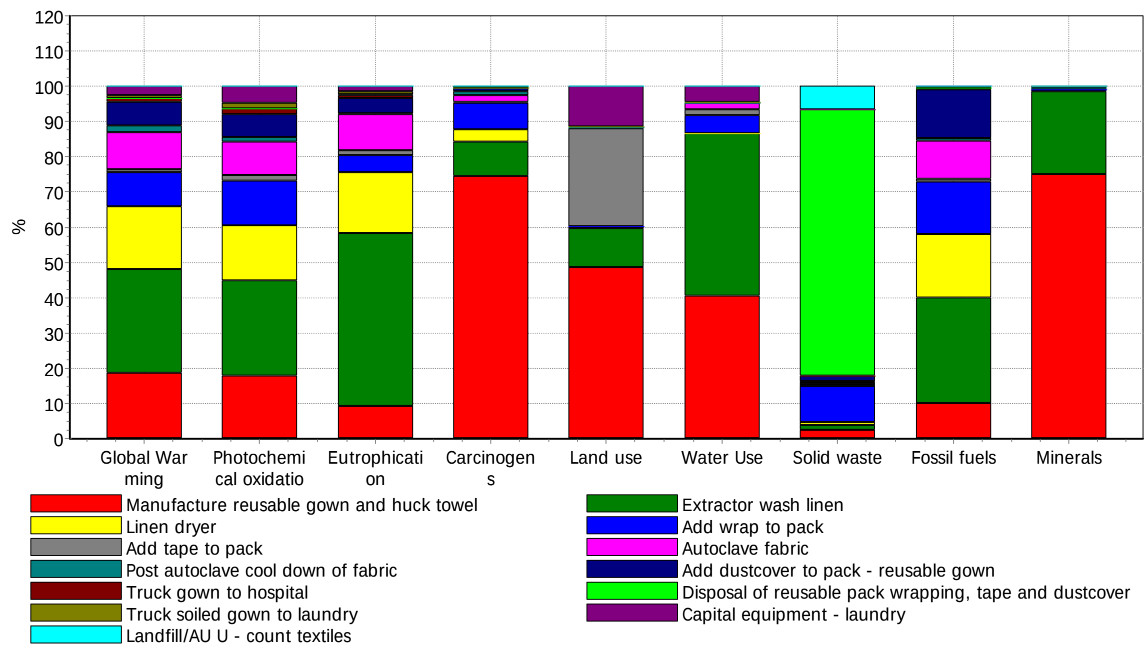

Figure 6-1 Drivers of environmental impacts - Characterised impact assessment - Reusable surgical pack.

The extractor wash process contributes a significant portion to each indicator with the exception of solid waste. Environmental impacts associated with the wash process are in turn driven by a number sub-process elements. Figure 6-2 illustrates how the hot water process (boiler fuel consumption) used in the wash process is a major contributor to global warming, photochemical oxidation, water use and fossil fuel indicators. The figure also illustrates the benefits (negative impacts) that the waste water treatment process which incorporates the recycling system, provides in most indicators. The waste water treatment process adversely drives eutrophication impacts due to the phosphorus content of the waste water flow to the sewer, associated with the detergent used.

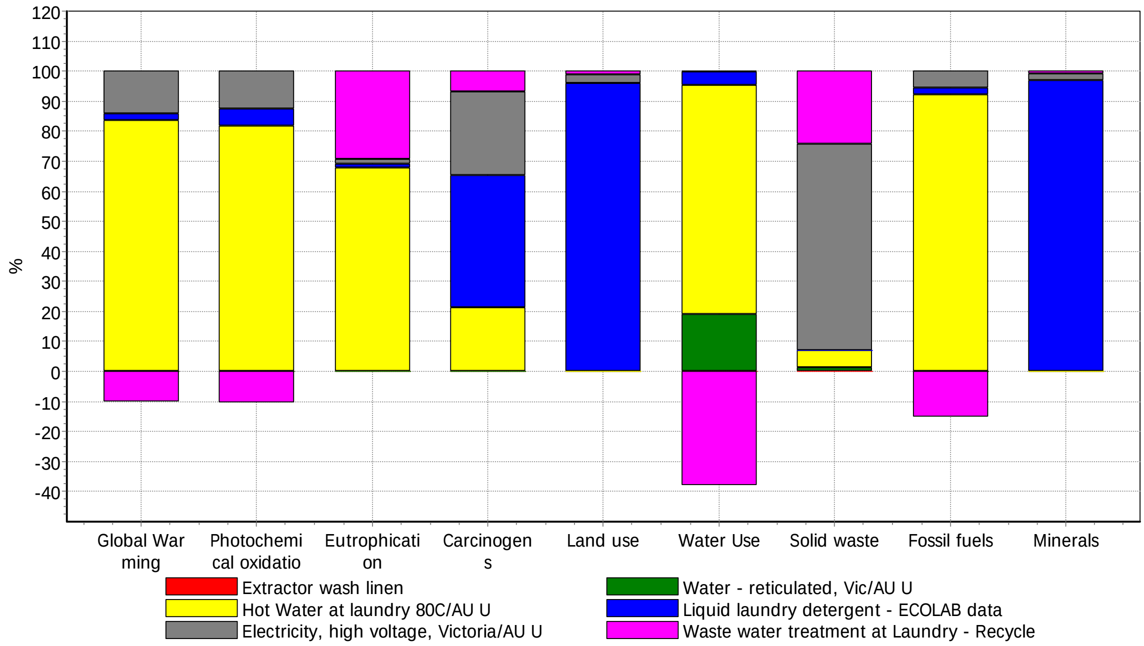

Figure 6-2 Extractor wash impact drivers - Characterised impact assessment shown – 1 kg linen.

Recycling system benefits, along with other drivers are further illustrated in the network diagrams shown in Figure 6-3. The diagrams show the benefit associated with water and energy recovery provided by the recycling system. It should be noted that the total characterisation described in Section 5.1 represents a summation of impacts and benefits shown in Figure 6-2 and Figure 6-3.

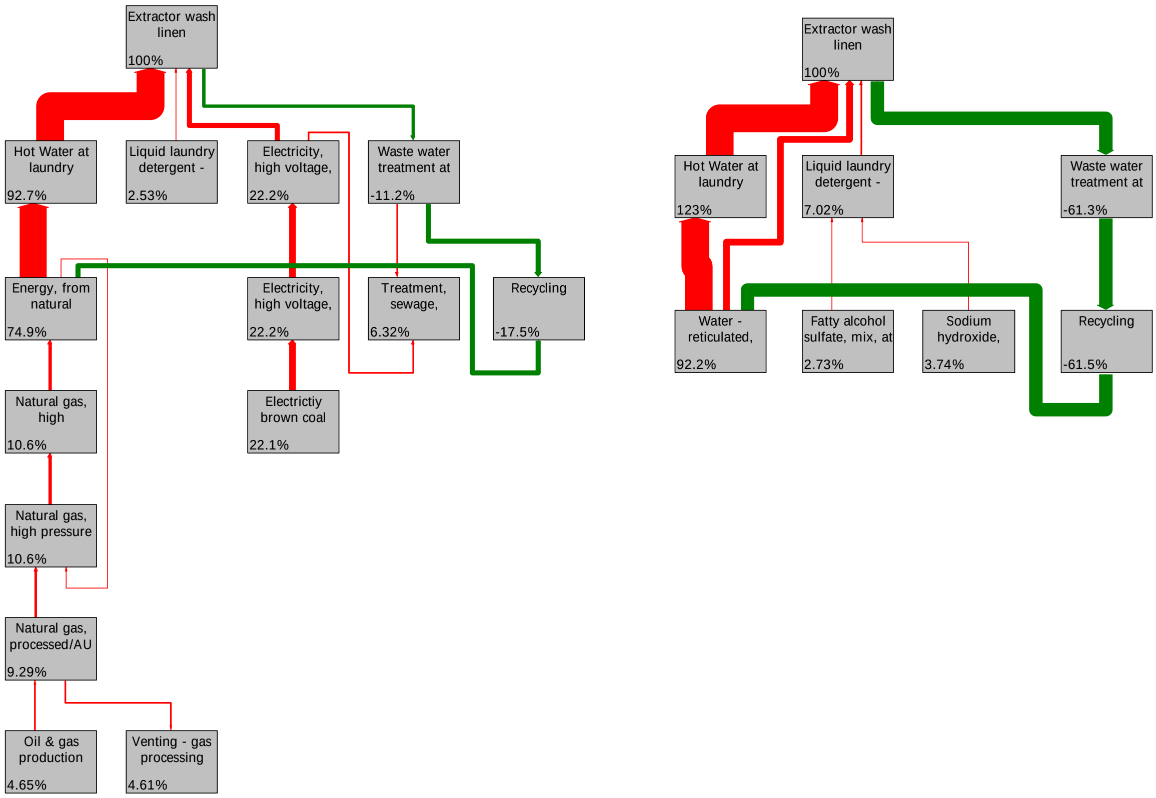

Figure 6-3 Network* diagram for extractor wash impacts. Left diagram shows global warming impact drivers (2% cutoff), right diagram shows water use divers (2% cutoff)

* Network diagrams - Each box on the chart represents a unit process involved in the life cycle of the item being considered. At the lower left corner of each process box is the contribution to the total impact that the respective process unit provides. The arrows in the chart reflect resulting flow of contribution from each process and their thickness reflects the relative importance. Note that in this figure adverse impacts are shown in red and offsetting positive impacts are shown in green.

Manufacturing impacts of the reusable gown and huck towel themselves, provided relatively minimal contributions to most indicators due the dilution effect of their long life cycles (manufacturing impacts are divided over 127 uses).

Of importance is the relatively large manufacturing impact of the huck towel in many indicators relative to the gown, which is physically much larger (refer Figure 6-4). This difference is due to the larger environmental impacts associated with cotton manufacture when compared to polyester.

Notably, transport impacts were found to be small contributors to most indicators.

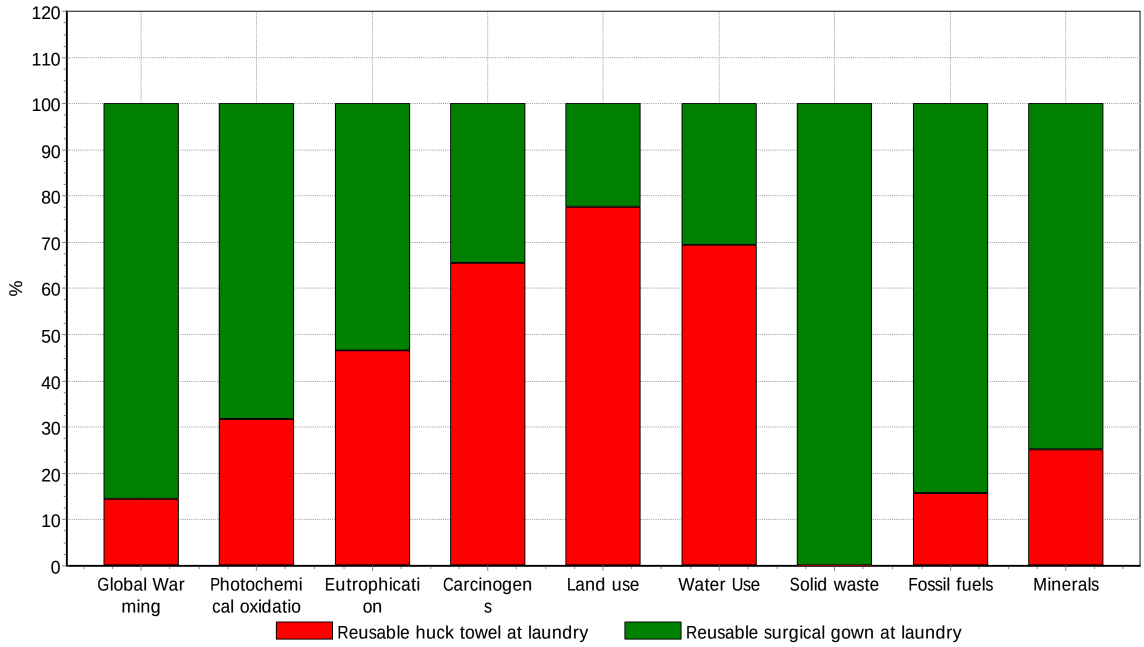

Figure 6-4 Percentage contribution of gown and huck towel to total manufacturing impacts.

6.2 Drivers of environmental impact – Disposable packs

The disposable gown life cycle is dominated by the impact of the gown and huck towel manufacturing processes, which is not surprising given the single use nature of the product. Figure 6-5 illustrates a breakdown of the contributing processes, showing that manufacturing process contributes greater than 75% of impacts in each indicator, with the exception of Solid Waste.

Figure 6-5 Drivers of environmental impacts - Characterised results - Disposable surgical pack.

An examination of the disposable gown manufacturing impacts shows that impacts are driven by the polypropylene granulate manufacturing process. Figure 6-6 illustrates the large contribution of polypropylene granulate and fabric manufacturing process to the overall disposable surgical pack manufacturing impact (in this case global warming is shown).

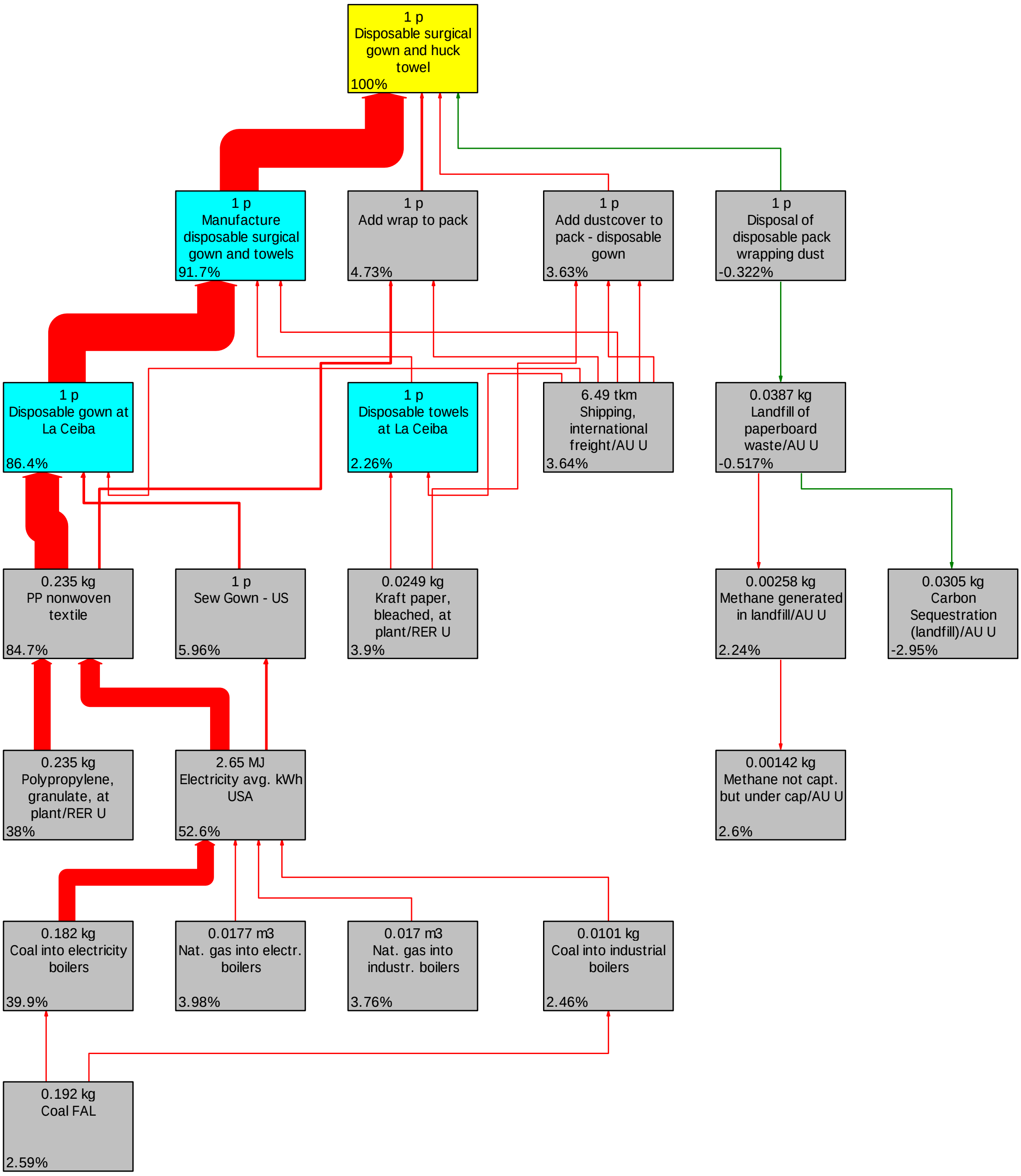

Figure 6-6 Global Warming network diagram* for a disposable surgical pack (contributions of 2% or greater shown).

* Network diagrams - Each box on the chart represents a unit process involved in the life cycle of the item being considered. At the lower left corner of each process box is the contribution to the total impact that the respective process unit provides. The arrows in the chart reflect resulting flow of contribution from each process and their thickness reflects the relative importance. Note that in this figure adverse impacts are shown in red and offsetting positive impacts are shown in green.

As with the reusable gown, the manufacture and disposal of the wrapping components of the surgical pack (the non-woven wrap and dustcover) also contribute to impacts in all the indicators, however these impacts are difficult to discern when compared to the impacts of gown and towel manufacture.

6.3 Water use impacts compared

The interest around water consumption in an Australian context is intense. For this reason it is worthwhile briefly discussing water consumption results determined by this study, and some of the limitations thereof. Table 5-1 shows that water consumption over the life cycle of a reusable gown is expected to be 110 litres and for the disposable gown, 140 litres. The result is at first surprising, especially when one considers that the disposable gown does not need to be washed, yet the reusable gown does need to be washed. The reason is that, the divers of water use are not just in the washing phase of gown life.

Figure 6-7 illustrates the drivers of water use for the reusable gown. As would be expected, much of the water used is consumed by the gown washing process. Surprisingly, a significant amount of water is also used to manufacture the huck-towel that is supplied with the pack. Given that this is a reusable item, the result is significant and highlights an opportunity to reduce impacts, by moving away from a cotton huck-towel.

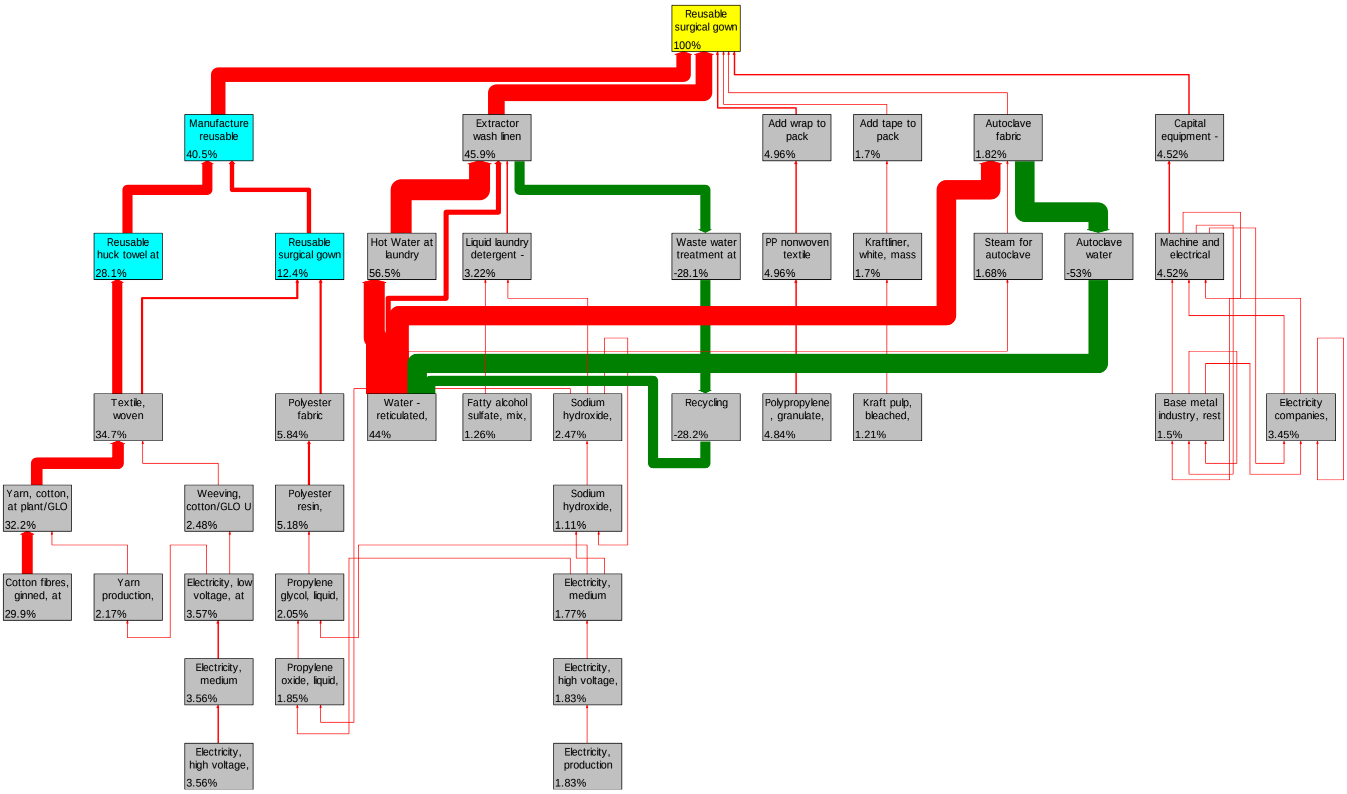

Figure 6-7 Water use drivers for the reusable gown life cycle (1% cutoff).

Figure 6-8 illustrates the drivers of impacts for the disposable gown. In this case the water use stems largely from the manufacture of polypropylene granulate used to produce the fabric. Although the gown does not need to be washed, significant amounts of water are used to produce it.

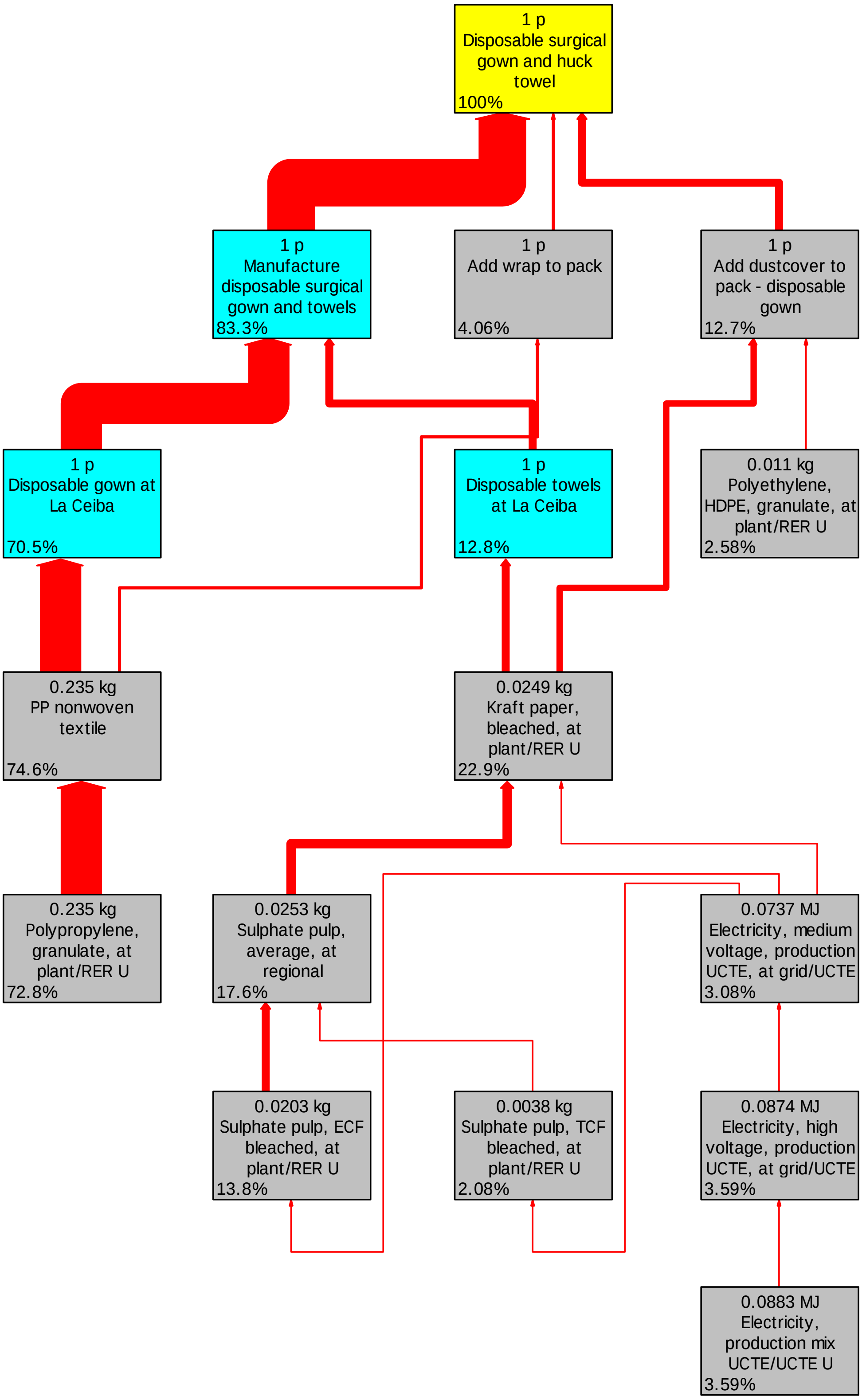

Figure 6-8 Water use drivers for the disposable gown life cycle (2% cutoff).

Of importance when considering water consumption in this context is that the LCA does not consider the regions within which water is being consumed. In this study water is being consumed in the United States for the disposable gown, because this is where the gown fabric is manufactured. For the reusable gown, water is being consumed locally in Melbourne, because this where the gown is washed. Reconciling the difference in impact associated with the local consumption versus the U.S. consumption is difficult. The assessment does not attempt to assess which form of water consumption is more damaging to the environment, local or overseas. Anecdotally, texts such as “Blue Covenant – The Global Water Crisis and the Coming Battle for the Right to Water” (Barlow 2007), suggest water scarcity is becoming a global issue, which is in keeping with the LCA impact assessment method used in this study.

7. Sensitivity analysis

A number of assumptions were made regarding the process inventories involved in the disposable and reusable surgical pack life cycles. To attempt to assess the impact of some of these assumptions, a number of sensitivity tests were undertaken to see if assumption changes would significantly change LCA conclusions.

Areas of particular uncertainty were selected and a sensitivity study undertaken in each area. Sensitivity analysis involved changing the parameter in question then reanalysing the LCA outcomes to see if conclusions changed significantly.

7.1 Reusable gown life

An important assumption in the LCA for reusable gowns was how long the gowns and huck towels last before they are disposed of. Shorter lifetimes would lead to an increase in impacts associated with gown and huck towel manufacture per use.

Figure 7-1 illustrates the results of the sensitivity that indicates that even if gown life is reduced to 50 uses, the LCA outcome remains directionally the same, however water use becomes higher for reusable gowns at approximately 90 uses. Any less than 90 uses and the disposable system will use less water.

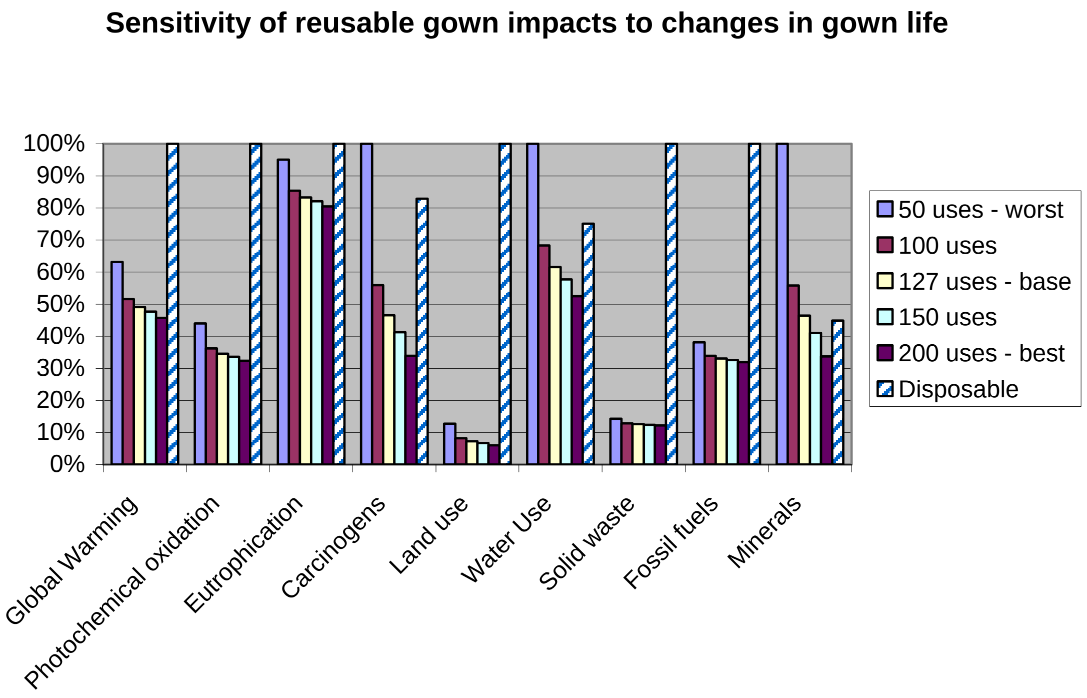

Figure 7-1 Sensitivity of reusable gown impacts to changes in gown life. Disposable gown impacts shown for reference.

7.2 Water recycling system

An important aspect of the laundry process that was included in the study was the use of a water recycling system to recover 40% of wastewater and 15% of water heating energy.

The sensitivity result shown in Figure 7-2 illustrates the impact of excluding recycling system benefits from the LCA study. This sensitivity is important because some laundries may not use such technology in their processes.

Although environmental impacts for the reusable packs were seen to increase, overall directional conclusions in each indicator remained the same.

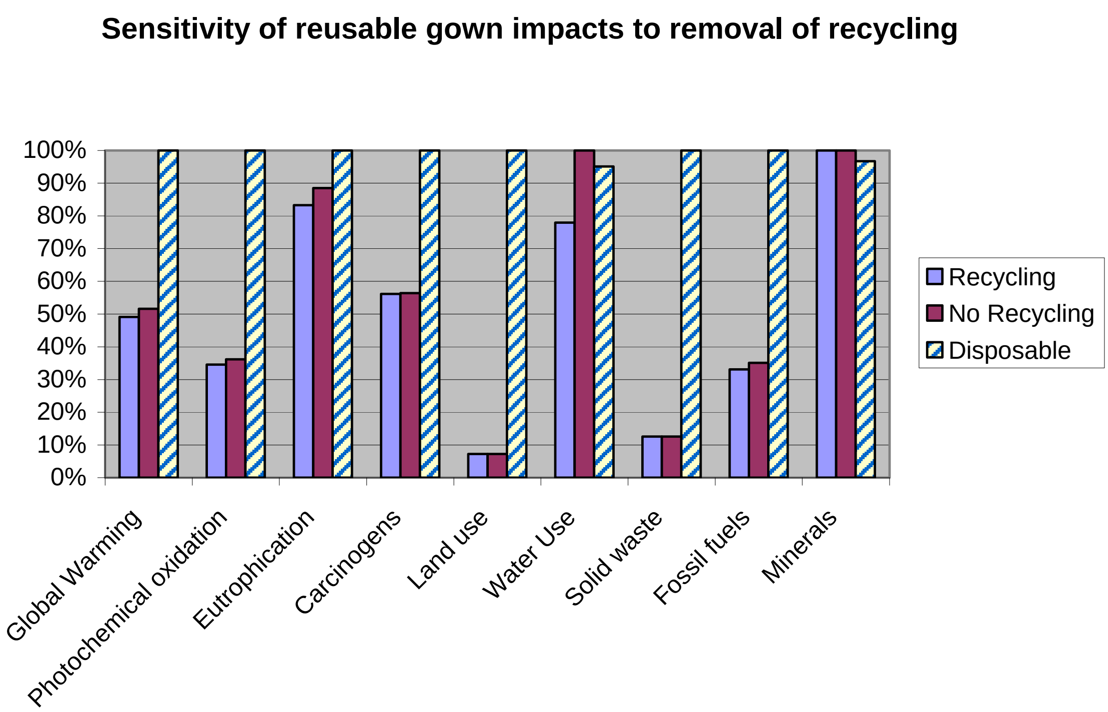

Figure 7-2 Sensitivity of reusable gown impacts to removal of water recycling. Disposable gown impacts shown for reference.

7.3 Average distance from hospital to laundry

Transport to and from the hospital of a reusable gown is a clear difference between the reusable and disposable life cycles. The LCA study assumes that this distance is 50km on average, however this may not be accurate in all cases. To test this assumption a number of distances were used and the overall impacts calculated.

Figure 7-3 illustrates the results of the sensitivity to transport distance of the reusable gown impacts, and shows little change in environmental outcomes. LCA conclusions remain directionally consistent at all distances considered.

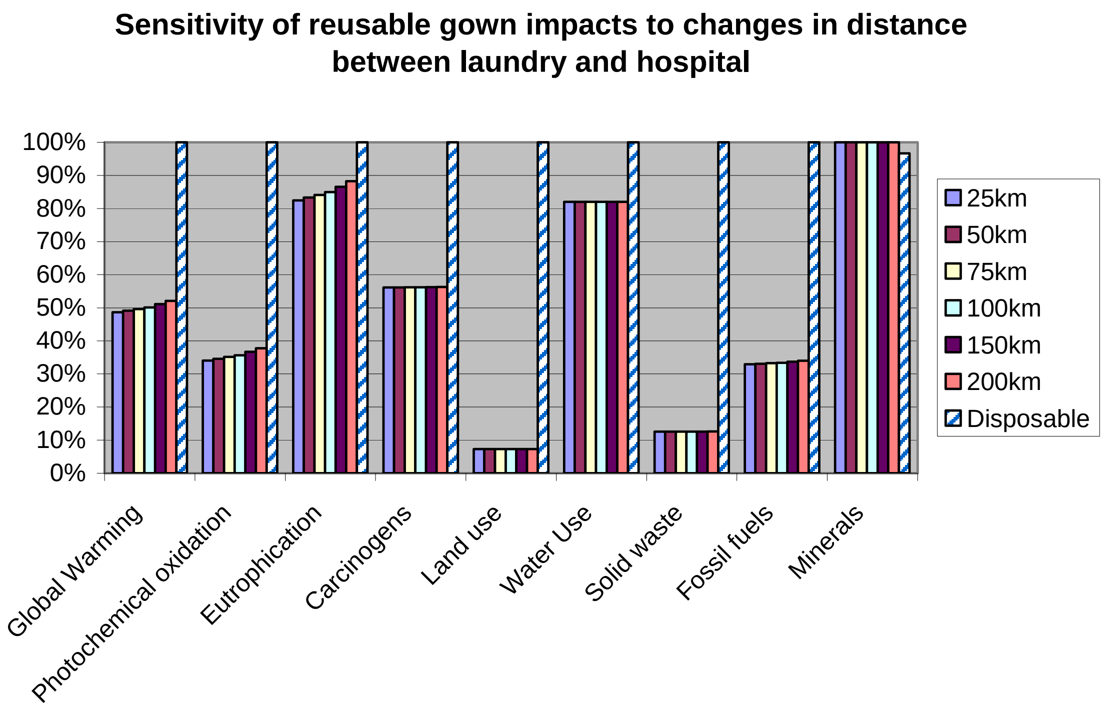

Figure 7-3 Sensitivity of reusable gown impacts to changes in distance between laundry and hospital. Disposable gown impacts shown for reference.

7.4 Disposable gown disposal at end of life

A key assumption of the study is that disposable gowns are sent to landfill once they are used. Although in many cases this may be true, it is also likely that the gowns could be incinerated if they have been contaminated and are considered a biological hazard by the hospital. In addition, there is also some work being undertaken by local distributors of disposable gowns to undertake recycling of the gowns when they are disposed of. In order to better understand the impacts of these alternative fates, an additional sensitivity study was undertaken.

The sensitivity considered 4 possible fates:

1. Base case – 100% gowns and towels disposed of to landfill
2. 100% gowns captured and recycled (towels disposed of to landfill). This scenario employed a polypropylene recycling model developed by the Centre for Design as part of prior studies undertaken.
3. 100% gowns and towels incinerated, without energy recovery
4. 100% gowns and towels incinerated, with energy recovery (uncommon in Australia)

Figure 7-4 illustrates the impacts associated with the alternative disposal methods relative to the impacts associated with the reusable gown and towel system. Although impacts, such as solid waste, can be significantly reduced under certain alternative disposal techniques, overall study conclusions remain directionally consistent.

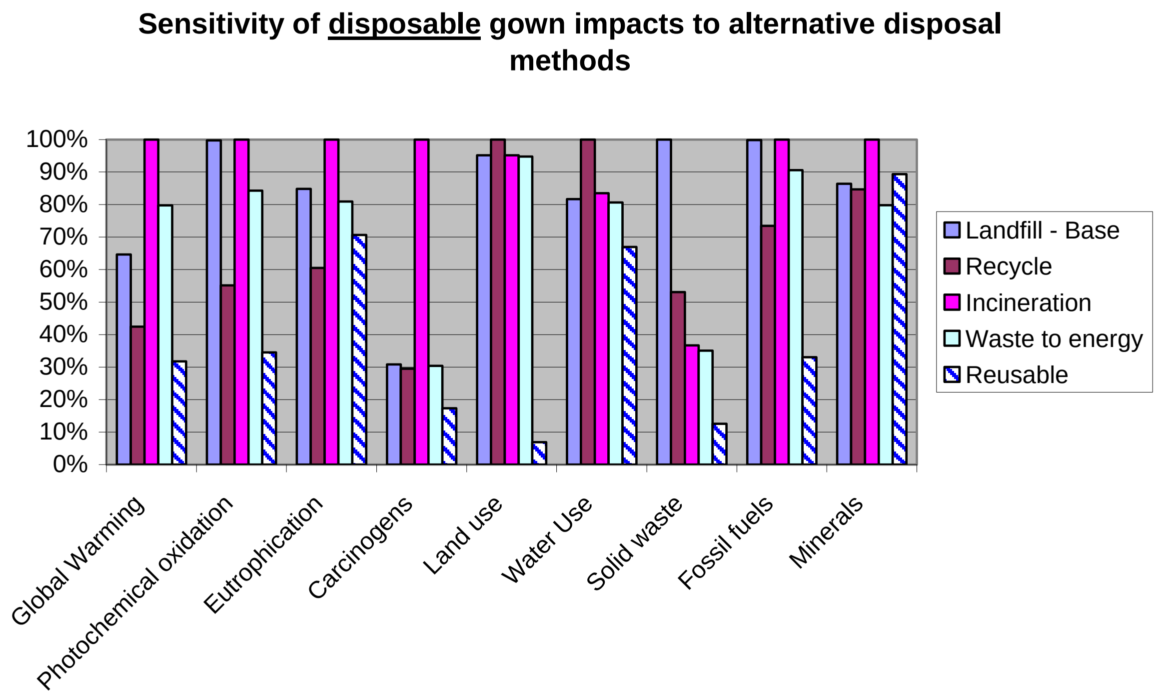

Figure 7-4 Sensitivity of disposable gown impacts to 100% recycling at end of life. Reusable gown impacts shown for reference.

7.5 Disposable gown materials

Feedback received as part of the disposable gown manufacturer survey undertaken (described in Section 3.1), mentioned that this study had only considered polypropylene non-woven gowns and not gowns made from other materials, particularly those materials containing wood pulp. In order to address this concern, an additional sensitivity was undertaken that modified the material used to manufacture the gown.

Detail regarding the content of pulp based disposable gown fabrics was difficult to attain. Instead a conservative estimate of impacts was developed from a simple inventory based on a composition of 50% sulphate pulp and 50% polyester. This estimate is based on McDowell(1993).

The life cycle inventory for the pulp based fabric was based on the material impacts only (no allowance for spinning or transport) of 50% sulphate pulp (Ecoinvent) and 50% polyester resin (Ecoinvent). Although grossly simplified the model provides a conservative basis for considering pulp based fabrics, and testing if conclusions are likely to be altered if such a material were to be used in place of a polypropylene non-woven material for the gown.

Material properties were assumed to be identical to those of polypropylene, which given the new material is pulp based, is conservative.

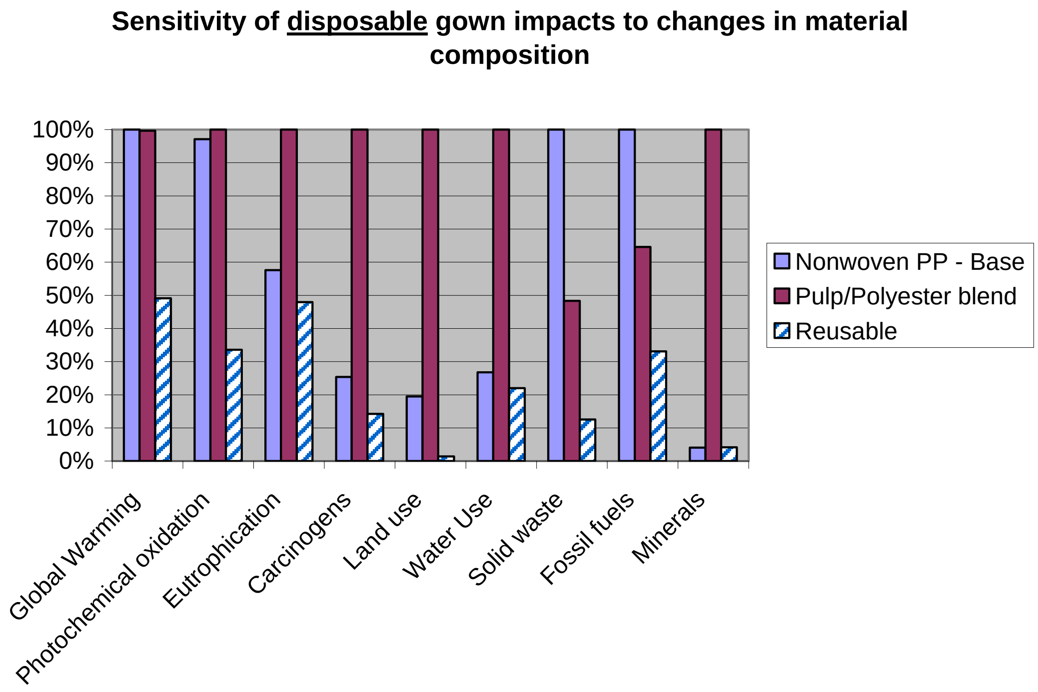

Figure 7-5 Sensitivity of disposable gown impacts to changes in material composition - characterised results shown

Figure 7-5 illustrates the life cycle impacts of a pulp/polyester based disposable gown, showing that, in general, impacts are increased, with the exception of solid waste (solid waste impacts are reduced due to the assumption of no energy requirements to manufacture fabric). Although the results shown do not accurately quantify the impacts of a pulp/polyester based surgical gown, they do suggest that such a material, will increase, rather than reduce disposable gown impacts in general.

7.6 Gown size

Although the gowns selected for this study were selected on the basis that each were considered a 'large' size and each was considered to provide the same degree of functionality, it became clear that the disposable gown tested was larger than the reusable gown considered. Although the functional unit of the study was not considered to be 'usage of fabric in the gown', it was considered important to test if study results would change if gowns were normalised to an identical area of fabric.

To undertake this sensitivity the area of fabric used in each gown was estimated, with the calculations and results shown in Table 7-1. The estimate showed that the disposable gown was 131% of the size of the reusable gown.

Table 7-1 Estimation of gown fabric area (area shown in square meters).

Area of body

	a	b	c	d	e	f
formula				axc	2*(0.5*c*(a-b)/2)	d-e
	Base W	Top W	Height	Box A	2xside A	Area
Reuse body	1.7	0.6	0.9	1.5	0.5	1.0
Dispose body	1.8	0.7	1.1	1.9	0.6	1.3

Area of arms

	g	h	i
formula			g*h*4
	Width	Length	Area
Reuse arms	0.2	0.6	0.6
Dispose arms	0.3	0.7	0.8

Total

	j	
formula	f+i	
	Total	% of resable
Reusable	1.58	100%
Disposable	2.07	131%

For this sensitivity study, the life cycle impacts were adjusted for the disposable gown – reducing its impacts to those that would be expected if it were an identical area to that of the reusable gown.

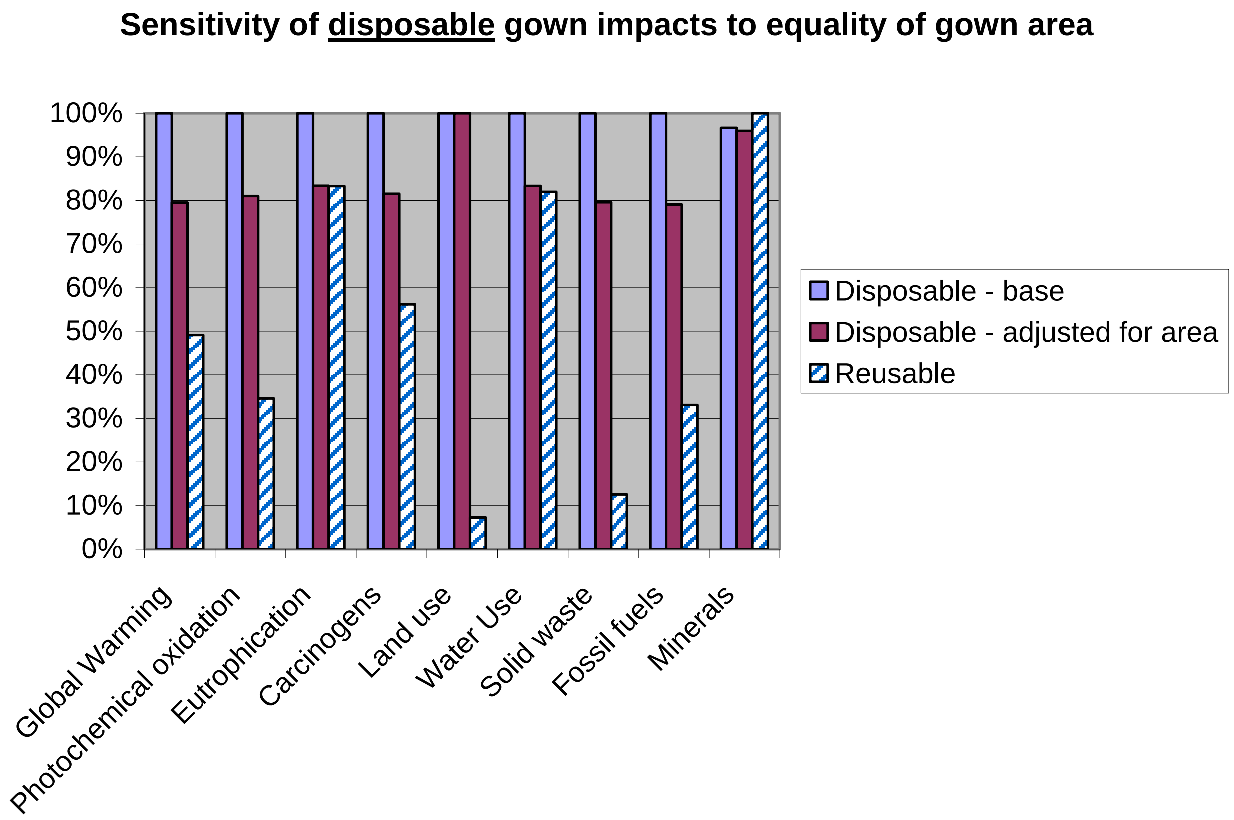

Figure 7-6 - Sensitivity to adjustment of disposable gown impacts for area.

The results shown in Figure 7-6, show that adjusting the disposable gown results for area does reduce impacts, but does not cot directionally alter the conclusions of the study. In other words, differences in gown size do not dramatically alter the study outcomes.

7.7 Phosphates in detergents

Under the base-case considered in this study, the laundry facility is assumed to operate using low-phosphate detergents to wash the returnable gowns (refer Section 4.2.4). Although low phosphate detergents were used in the laundry facilities considered in this study, it may not always be true of all laundries. Some laundries may still use phosphate based detergents, many of which contain the builder element sodium tri-polyphosphate (STPP).

The sensitivity considered in this section addresses the impacts of using a traditional phosphate based detergent (that uses STPP) in place of the low-phosphate detergent used in the the base case. In to undertake the sensitivity, manufacturing impacts and dosing for the phosphate based detergent were assumed to be the same as those for the low phosphate detergent, however phosphate emissions were recalculated. A recalculation of phosphate emissions was undertaken using the nutrient-balance approach described in Appendix E.

The resulting impacts are shown in Figure 7-7.

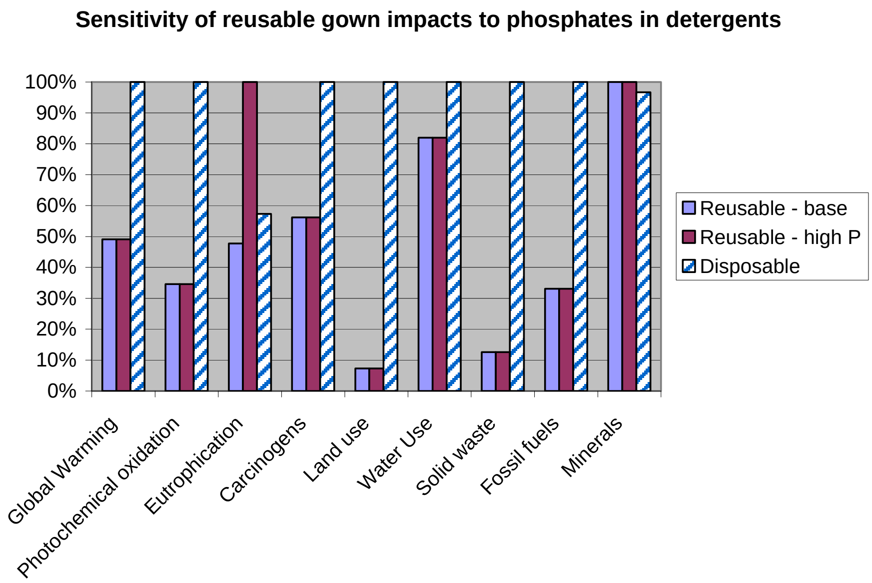

Figure 7-7 Sensitivity of reusable gown impacts to changes in the phosphate content of detergents.

Figure 7-7 illustrates the significant change in potential eutrophication impacts associated with phosphate based detergents. In this case the eutrophication impacts of the reusable gown become significantly higher than the disposable gown.

8. Other studies

Two alternative studies were reviewed. The first, “An Environmental, Economic, and Health Comparison of Single-Use and Reusable Surgical Drapes and Gowns” (McDowell 1993), involved a broad range of assessment methods to compare a pulp and polyester “Fabric450” disposable gown to a series of reusable gowns. A summary of the inventory aspects of the report is shown in Table 8-1.

Table 8-1 McDowell (1993) Inventory Results (functional unit is 100 surgical procedures)

	Unit	Reusable	Disposable	Summary conclusion
Uses	number	85	1	
Water	litres	7.5E+01	4.0E+00	Reusable greater water use
Energy	MJ	2.9E-02	7.2E-02	Disposable greater energy use
CO2	kg	5.3E-03	9.9E-01	Disposable greater global warming
Solid waste	kg	7.0E-02	1.4E+00	Disposable greater solid waste

The McDowell study also covered clinical efficacy, economics and other aspects, beyond the scope of this study. Water use is the only surprising aspect of McDowell’s study, given that the disposable gowns were manufactured from a pulp-polyester blend.

A further study has been undertaken by the European Textile Services Association (2002), has been published in summary form on the internet. Unfortunately, it is only published in summary form so cannot be easily tested. It concludes as follows:

> “The best case scenarios show that, with one exception, reusable gowns have lower environmental impacts than disposable gowns in the categories measured. The exception is the 50%/50% cotton/polyester mix which uses more water over its life cycle than any of the others.
>
> In the worst case scenarios, reusable gowns still perform better than disposables, but the differences are reduced. Once again, the exception is cotton/polyester which also does poorly on global warming potential.”

The above conclusions appear broadly consistent with those arrived at in this study, with the exception of water use mentioned in McDowell.

Both studies considered above draw conclusions regrading inventory and impacts associated with reusable versus disposable gown systems. Unfortunately, neither presents sufficient detail to allow checking of system boundaries, allocation methods, characterisation factors or other considerations. There is also no statement in either report regarding peer review or compliance with ISO 14044.

9. Recommendations

Potential exists to reduce the environmental impacts of disposable and reusable surgical packs even further. Some of the more obvious opportunities are listed in the following sections.

9.1 Reusable surgical pack improvement opportunities

Manufacture the huck towel out of a polyester blend material (similar to the gown)

Cotton that is currently used in the huck towel requires significantly more water to produce than does polyester. This change would significantly reduce impacts, particularly Water Use.

If synthetic material not possible, it may make sense to make the huck towel disposable, like the single use gown and towel pack (paper towels have a lower impact than a cotton huck-towel)

Integrate huck towel and non-woven wrap functionality

Given the similar size of the wrap and the huck towel it may be possible to use the one component to perform both functions. This would eliminate a component from the pack.

Minimise disposable components

Significant environmental impacts are generated by the manufacture and disposal of the disposable components of the reusable pack system. Replacing components such as the non-woven wrap and dust cover with reusable equivalents should be investigated, as environmental impacts would likely be reduced.

Ensure Recycling type technology is applied

The Recycling process provides significantly reduced impacts compared to laundries that do not use the process (40% water saving, 15% energy saving). Ensuring all laundries use Recycling would ensure that the results presented in this report are consistently achieved.

Consider waste water processing to extract phosphates

Eutrophication impacts may be reduced if a phosphate extraction process could be added to the laundry wastewater treatment system. Note that an LCA would be required to ensure that the additional treatment processes required actually achieved net environmental benefits.

9.2 Disposable pack improvement opportunities

Recycle disposable components at end of life and reprocess

Large improvements in the environmental impacts of the disposable surgical packs could be achieved if gowns and huck towels could be reliably recycled.

10. Conclusions

Although extensive information was available regarding the reusable surgical gown life cycle, very little information was supplied with respect to the disposable gown life cycle. For this reason the Life Cycle Inventory had to be constructed largely from industry survey results and publicly available data for disposable gowns, which is not as robust as actual process data. For this reason a number of sensitivity analyses were undertaken that attempt to address uncertainties in assumptions made, and to verify the appropriateness of conclusions drawn.

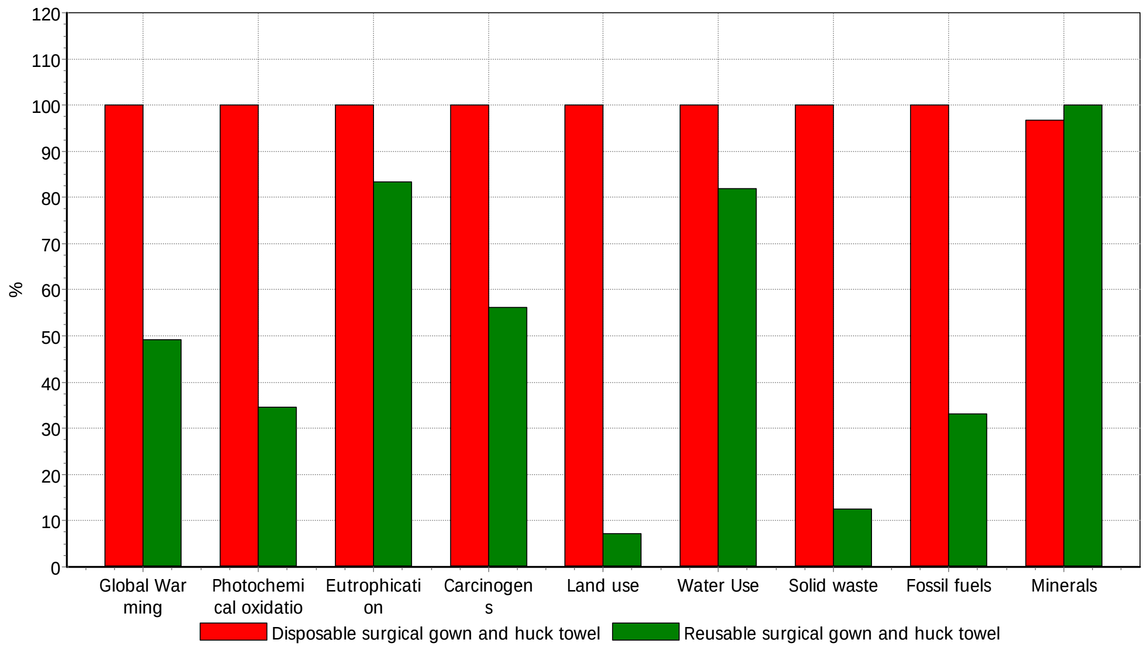

Figure 10-1 Comparison of life cycle impacts of disposable versus reusable surgical packs.

Overall, reusable gowns were found to generate lesser environmental impacts in global warming, photochemical oxidation, eutrophication, carcinogens, land use, water use, solid waste and fossil fuels. Disposable gowns faired better in the minerals category (refer Figure 10-1).

In general, disposable gowns had higher impacts in most categories because environmental impacts associated with gown manufacture were incurred for each gown use. This is in contrast to the reusable gown life cycle, which although incurring washing impacts, the gown survives over multiple uses, so only a small portion of manufacturing impacts are incurred at each use.

Although disposable gowns performed better in the mineral scarcity indicator, the reduction versus a reusable gown and towel pack was minimal. Normalised results also suggest that mineral impacts form a far smaller proportion of the total per-capita impact of the average Australian, than some of the other indicators considered (refer Figure 5-2).

Although the disposable gown was shown to consume water to a greater degree than the reusable gown, concluding as to the exact nature of environmental damage in this indicator is difficult. The consumption of water associated with the disposable gown is largely driven by manufacturing in the United States, however water consumption of the reusable gown is largely associated with water consumed locally in the washing process (refer Section 6.3).

Opportunities were found to reduce the environmental impacts of both reusable and disposable gowns. Reusable gown impacts could be improved by:

- Manufacturing the huck towel out of a polyester blend material (similar to the gown)
- Integrating huck towel and non-woven wrap functionality
- Minimising disposable components
- Ensuring Recycling type technology is applied at all laundries
- Considering waste water processing to extract phosphates

Disposable gown impacts could be improved primarily by ensuring gowns are recycled at the end of their lives.

In conclusion, the reusable gown was shown to generate reduced environmental impacts versus the disposable gown in most impact indicators considered. The reduced impacts of the reusable gown were primarily associated with the extended life of the gown, which in turn reduces the manufacturing impacts associated with each gown use. In contrast, the disposable gown's manufacturing impacts are fully incurred each time a gown is used.

10.1 Limitations of findings

This LCA study has compared the life cycle impacts of reusable surgical gowns with disposable gowns using data provided by reusable gown and disposable gown industry participants. Data quality achieved is believed to be suitable for the general comparison of systems in a typical urban application and provides directional guidance as to the impacts involved. Detailed quantification of impacts will vary between specific applications, often driven by the factors discussed in the sensitivity analysis (refer Section 7).

It should also be noted that the base case reusable system assessed includes water recycling, which may not be applied in all cases. Users considering reusable products that do not incorporate this technology should consider the sensitivity study undertaken in Section 7.2.

Low phosphate detergents were also assumed in this study which may not be used by all laundry service providers. Use of traditional, high phosphate detergents significantly increases eutrophication impacts of the reusable gown above those of the disposable gown shown in this study (other indicators would not be significantly affected). Users considering reusable products that use traditional phosphate based detergents should consider the sensitivity study undertaken in Section 7.7.

Finally, it is believed that further work could be undertaken to improve the quality of data used in this study. An area where data could be further improved would be in the manufacture of non-woven fabrics used in disposable gowns.

11. References

11.1 Sima Pro® databases utilised

Database name	Description
Ecoinvent	A large, network-based database and efficient calculation routines are required for handling, storage, calculation and presentation of data and are developed in the course of the project. These components partly take pattern from preceding work performed at ETH Zurich (Frischknecht & Kolm 1995). Incorporates Ecoinvent 2.0.
Franklin 98 S5	The Franklin library consists of life cycle inventory (LCI) data based upon experience of companies operating in the USA, statistical and literature sources.
Ausdata 2007	Australian LCA database developed from 1998 up to 2007 by Centre for Design from data originally developed with the CRC for Waste Management and Pollution Control as part of an Australian Inventory data project. The data from this project has been progressively updated particularly the data for metals production, energy, transport and paper and board production.

11.2 Other data sources, abbreviated in inventory:

E-Tex – contact with polyester blend fabric importer and gown manufacturer based in Melbourne, Australia.

Getinge – Manufacturer of autoclave equipment. Melbourne office contacted.

Laundry – A local (Melbourne based) industrial laundry engaged in managing a returnable gown process was used for the bulk of the reusable process study.

Weighed – the mass data is based on weight results collected from a surgical pack.

11.3 Literature and other references

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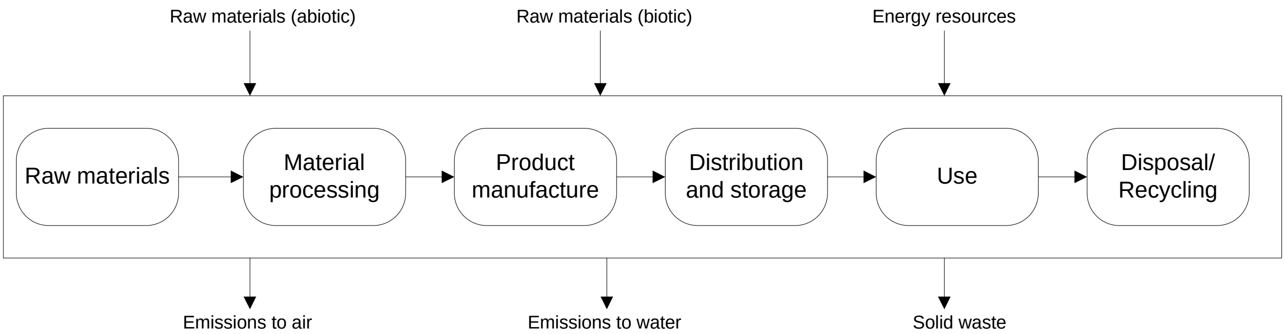
Appendix A Life Cycle Assessment (LCA)

LCA is the process of evaluating the potential effects that a product, process or service has on the environment over the entire period of its life cycle. Figure Appx. A-1 illustrates the life cycle system concept of natural resources and energy entering the system with products, waste and emissions leaving the system.

Figure Appx. A-1 Life cycle stages.

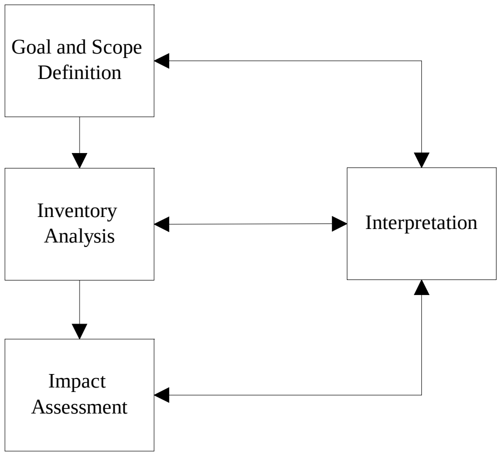


The International Standards Organisation (ISO) has defined LCA as (AS/NZS ISO 14041:1998):

> "a technique for assessing the environmental aspects and potential impacts associated with a product by:
>
> - Compiling an inventory of relevant inputs and outputs of a product system;
> - Evaluating the potential environmental impacts associated with those inputs and outputs; and
> - Interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study".

The technical framework for LCA consists of four components, each having a very important role in the assessment. They are interrelated throughout the entire assessment and in accordance with the current terminology of the International Standards Organisation (ISO). The components are goal and scope definition, inventory analysis, impact assessment and interpretation as illustrated in Figure Appx. A-2 and explained below.

Figure Appx. A-2 The components of an LCA (AS/NZS 1998



A.1.1 Goal and scope definition

At the commencement of an LCA, the goal and scope of the study needs to be clearly defined. The goal should state unambiguously the intended application/purpose of the study, the audience for which the results are intended, the product or function that is to be studied, and the scope of the study. When defining the scope, consideration of the functional unit, system boundaries and data quality requirements are some of the issues to be covered.

A.1.2 Inventory analysis

Inventory analysis is concerned with the collection, analysis and validation of data that quantifies the appropriate inputs and outputs of a product system. The results include a process flow chart and a list of all environmental inventories (inventory table) that are associated with the product under study.

A.1.3 Impact assessment

The primary aim of an impact assessment is to identify and establish a linkage between the product's life cycle and the potential environmental impacts associated with it. The impact assessment stage consists of three phases that are intended to evaluate the significance of the potential environmental effects associated with the product system.

A.1.4 Interpretation

Interpretation is a systematic evaluation of the needs and opportunities to reduce the environmental burden, such as changes in product, process and service design, and reductions in raw material and/or energy usage.

Appendix B Survey of disposable gown manufacturers

Key learning's from disposable manufacturer survey are listed below. Three manufacturers surveyed, of which two provided detailed responses.
manufacturers surveyed, of which two provided detailed responses.

Issue raised	Action
Functional unit needs to compare products that perform (bleed through) to an equivalent standard	• Added section highlighting that disposable gowns may perform at a higher level for gown bleed through. • European standards added and referenced (although not applicable in Australia).
Lack of differentiation between local impacts and overseas impacts.	• Added discussion on water use and regionality • Highlighted that LCA does not distinguish between local and global impacts (in this study)
Study does not take into account other factors	• Functional unit exclusions added
Vacuum packing improves transport efficiency	• Transport not a driver in this study, so nothing added on this issue
System boundary does not account for linen manufacture properly	• Added language that makes clear that all linen manufacturing and agricultural processes are included
Sterilisation should be added to disposable gown process	• Sterilisation excluded from study in the interests of conservatism. No information was provided so inclusion would have been difficult.
Gown size not properly considered	• Gown sizing addressed as a sensitivity study
Disposable gown material not necessarily polypropylene	• Spunlace pulp added as a sensitivity study
Country of manufacture should be in Asia not Americas, however fabric manufactured in USA.	• Manufacturing locations partially amended: o Fabric manufactured in USA o Gown sewn and packed in Honduras o Product packaging states: "Made in Honduras" o No change to incorporate Asian point of manufacture
Polypropylene study too old	• No action. Best work done to date. Probably conservative as European energy used.
Gown and huck towel assembly not undertaken in Melbourne	• Changed assumption so that assembly undertaken in Honduras.
Wrap material incorrect	• Impact of wrap material minimal in study. As no alternative provided, no changes made.
Trucking utilisation confusing	• Improve trucking utilisation explanation
Disposal should be via incineration (recommended)	• Added incineration disposal as a sensitivity. • Added energy recovery as a sensitivity (although unlikely in Australia).
Waste needs to be considered – theft etc	• Loss rates included in reusable study • Number of uses added as a sensitivity
Chemicals added to gown to make impermeable need to be considered	• No chemicals could be identified. Expect minimal impact given reuse of item.
Non-woven fabrics have incorrect manufacturing energies	• As advised, all electrical energy to be used for spin process • 10MJ per kg to be used • Updated manufacturing to incorporate new data above.

Appendix C Characterisation and Normalisation factors

Columns as follows:

Compartment Subcompartment Substance CAS number Amount Unit

Compartment	Subcompartment	Substance	CAS number	Amount	Unit
Global Warming	**kg CO2**				
Air	(unspecified)	Trifluoromethylsulfur pentafluoride	000373-80-8	17700	kg CO2 / kg
Air	(unspecified)	Sulfur hexafluoride	002551-62-4	23900	kg CO2 / kg
Air	(unspecified)	Propane, perfluoro-	000076-19-7	7000	kg CO2 / kg
Air	(unspecified)	Propane, 3,3-dichloro-1,1,1,2,2-pentafluoro-, HCFC-225ca	000422-56-0	122	kg CO2 / kg
Air	(unspecified)	Propane, 1,3-dichloro-1,1,2,2,3-pentafluoro-, HCFC-225cb	000507-55-1	595	kg CO2 / kg
Air	(unspecified)	Propane, 1,1,2,2,3-pentafluoro-, HFC-245ca	000679-86-7	560	kg CO2 / kg
Air	(unspecified)	Propane, 1,1,1,3,3,3-hexafluoro-, HCFC-236fa	000690-39-1	6300	kg CO2 / kg
Air	(unspecified)	Propane, 1,1,1,3,3-pentafluoro-, HFC-245fa	000460-73-1	1030	kg CO2 / kg
Air	(unspecified)	Propane, 1,1,1,2,3,3,3-heptafluoro-, HFC-227ea	000431-89-0	2900	kg CO2 / kg
Air	(unspecified)	PFPMIE		10300	kg CO2 / kg
Air	(unspecified)	PFC-9-1-18		7500	kg CO2 / kg
Air	(unspecified)	Pentane, perfluoro-	000678-26-2	7500	kg CO2 / kg
Air	(unspecified)	Pentane, 2,3-dihydroperfluoro-, HFC-4310mee	138495-42-8	1300	kg CO2 / kg
Air	(unspecified)	Nitrogen fluoride	007783-54-2	17200	kg CO2 / kg
Air	(unspecified)	Methane, trifluoro-, HFC-23	000075-46-7	11700	kg CO2 / kg
Air	(unspecified)	Methane, trichlorofluoro-, CFC-11	000075-69-4	4750	kg CO2 / kg
Air	(unspecified)	Methane, tetrafluoro-, CFC-14	000075-73-0	6500	kg CO2 / kg
Air	(unspecified)	Methane, tetrachloro-, CFC-10	000056-23-5	1400	kg CO2 / kg
Air	(unspecified)	Methane, monochloro-, R-40	000074-87-3	13	kg CO2 / kg
Air	(unspecified)	Methane, fluoro-, HFC-41	000593-53-3	150	kg CO2 / kg
Air	(unspecified)	Methane, difluoro-, HFC-32	000075-10-5	650	kg CO2 / kg
Air	(unspecified)	Methane, dichlorodifluoro-, CFC-12	000075-71-8	10900	kg CO2 / kg
Air	(unspecified)	Methane, dichloro-, HCC-30	000075-09-2	8.7	kg CO2 / kg
Air	(unspecified)	Methane, chlorotrifluoro-, CFC-13	000075-72-9	14400	kg CO2 / kg
Air	(unspecified)	Methane, chlorodifluoro-, HCFC-22	000075-45-6	1810	kg CO2 / kg
Air	(unspecified)	Methane, bromotrifluoro-, Halon 1301	000075-63-8	7140	kg CO2 / kg
Air	(unspecified)	Methane, bromochlorodifluoro-, Halon 1211	000353-59-3	1890	kg CO2 / kg
Air	(unspecified)	Methane, bromo-, Halon 1001	000074-83-9	5	kg CO2 / kg
Air	(unspecified)	Methane, biogenic	000074-82-8	21	kg CO2 / kg
Air	(unspecified)	Methane	000074-82-8	21	kg CO2 / kg
Air	(unspecified)	HFE-7100		297	kg CO2 / kg
Air	(unspecified)	HFE-43-10pccc124 (H-Galden1040x)		1870	kg CO2 / kg
Air	(unspecified)	HFE-347pcf2		580	kg CO2 / kg
Air	(unspecified)	HFE-338pcc13 (HG-01)		1500	kg CO2 / kg
Air	(unspecified)	HFE-236ca12 (HG-10)		2800	kg CO2 / kg
Air	(unspecified)	Hexane, perfluoro-	000355-42-0	7400	kg CO2 / kg
Air	(unspecified)	Ether, pentafluoromethyl-, HFE-125	003822-68-2	14900	kg CO2 / kg
Air	(unspecified)	Ether, difluoromethyl 2,2,2-trifluoroethyl-, HFE-245fa2	001885-48-9	659	kg CO2 / kg
Air	(unspecified)	Ether, difluoromethyl 2,2,2-trifluoroethyl-, HFE-245cb2	001885-48-9	708	kg CO2 / kg
Air	(unspecified)	Ether, di(difluoromethyl), HFE-134	001691-17-4	6320	kg CO2 / kg
Air	(unspecified)	Ether, 1,1,2,3,3,3-Hexafluoropropyl methyl-, HFE-356pcc3	000382-34-3	110	kg CO2 / kg
Air	(unspecified)	Ether, 1,1,2,2-Tetrafluoroethyl methyl-, HFE-254cb2	000425-88-7	359	kg CO2 / kg
Air	(unspecified)	Ether, 1,1,2,2-Tetrafluoroethyl 2,2,2-trifluoroethyl-, HFE-347mcc3	000406-78-0	575	kg CO2 / kg
Air	(unspecified)	Ether, 1,1,1-trifluoromethyl methyl-, HFE-143a	000421-14-7	756	kg CO2 / kg
Air	(unspecified)	Ethane, pentafluoro-, HFC-125	000354-33-6	2800	kg CO2 / kg
Air	(unspecified)	Ethane, hexafluoro-, HFC-116	000076-16-4	9200	kg CO2 / kg
Air	(unspecified)	Ethane, chloropentafluoro-, CFC-115	000076-15-3	7370	kg CO2 / kg
Air	(unspecified)	Ethane, 2,2-dichloro-1,1,1-trifluoro-, HCFC-123	000306-83-2	77	kg CO2 / kg
Air	(unspecified)	Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124	002837-89-0	609	kg CO2 / kg
Air	(unspecified)	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	000076-14-2	10000	kg CO2 / kg
Air	(unspecified)	Ethane, 1,2-dibromotetrafluoro-, Halon 2402	000124-73-2	1640	kg CO2 / kg
Air	(unspecified)	Ethane, 1,1,2,2-tetrafluoro-, HFC-134	000359-35-3	1000	kg CO2 / kg
Air	(unspecified)	Ethane, 1,1,2-trifluoro-, HFC-143	000430-66-0	300	kg CO2 / kg
Air	(unspecified)	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	000076-13-1	6130	kg CO2 / kg
Air	(unspecified)	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	000811-97-2	1300	kg CO2 / kg
Air	(unspecified)	Ethane, 1,1,1-trifluoro-, HFC-143a	000420-46-2	3800	kg CO2 / kg
Air	(unspecified)	Ethane, 1,1,1-trichloro-, HCFC-140	000071-55-6	146	kg CO2 / kg
Air	(unspecified)	Ethane, 1,1-difluoro-, HFC-152a	000075-37-6	140	kg CO2 / kg
Air	(unspecified)	Ethane, 1,1-dichloro-1-fluoro-, HCFC-141b	001717-00-6	725	kg CO2 / kg
Air	(unspecified)	Ethane, 1-chloro-2,2,2-trifluoro-(difluoromethoxy)-, HCFE-235da2	026675-46-7	350	kg CO2 / kg
Air	(unspecified)	Ethane, 1-chloro-1,1-difluoro-, HCFC-142b	000075-68-3	2310	kg CO2 / kg
Air	(unspecified)	Dinitrogen monoxide	010024-97-2	310	kg CO2 / kg
Air	(unspecified)	Dimethyl ether	000115-10-6	1	kg CO2 / kg
Air	(unspecified)	Carbon dioxide, fossil	000124-38-9	1	kg CO2 / kg
Soil	(unspecified)	Carbon dioxide, biogenic		-1	kg CO2 / kg
Air	(unspecified)	Carbon dioxide, biogenic	000124-38-9	0	kg CO2 / kg
Air	(unspecified)	Carbon dioxide	000124-38-9	1	kg CO2 / kg
Air	(unspecified)	Butane, perfluorocyclo-, PFC-318	000115-25-3	8700	kg CO2 / kg
Air	(unspecified)	Butane, perfluoro-	000355-25-9	7000	kg CO2 / kg
Air	(unspecified)	Butane, nonafluoroethoxy, HFE-569sf2	163702-05-4	59	kg CO2 / kg
Air	(unspecified)	Butane, 1,1,1,3,3-pentafluoro-, HFC-365mfc	000406-58-6	794	kg CO2 / kg

Photochemical oxidation	kg C2H4			
Air	(unspecified)	VOC, volatile organic compounds		0.398 kg C2H4 / kg
Air	(unspecified)	Undecane	001120-21-4	0.384 kg C2H4 / kg
Air	(unspecified)	Toluene, 4-ethyl-	000622-96-8	0.906 kg C2H4 / kg
Air	(unspecified)	Toluene, 3,5-diethyl-	002050-24-0	1.295 kg C2H4 / kg
Air	(unspecified)	Toluene, 3-ethyl-	000620-14-4	1.019 kg C2H4 / kg
Air	(unspecified)	Toluene, 2-ethyl-	000611-14-3	0.898 kg C2H4 / kg
Air	(unspecified)	Toluene	000108-88-3	0.637 kg C2H4 / kg
Air	(unspecified)	t-Butyl methyl ether	001634-04-4	0.175 kg C2H4 / kg
Air	(unspecified)	t-Butyl ethyl ether	000637-92-3	0.244 kg C2H4 / kg
Air	(unspecified)	t-Butyl alcohol	000075-65-0	0.106 kg C2H4 / kg
Air	(unspecified)	t-Butyl acetate	000540-88-5	0.053 kg C2H4 / kg
Air	(unspecified)	Sulfur oxides		0.048 kg C2H4 / kg
Air	(unspecified)	Sulfur dioxide	007446-09-5	0.048 kg C2H4 / kg
Air	(unspecified)	Styrene	000100-42-5	0.142 kg C2H4 / kg
Air	(unspecified)	s-Butyl acetate	000105-46-4	0.275 kg C2H4 / kg
Air	(unspecified)	Propylene glycol t-butyl ether	057018-52-7	0.463 kg C2H4 / kg
Air	(unspecified)	Propylene glycol methyl ether	000107-98-2	0.355 kg C2H4 / kg
Air	(unspecified)	Propylene glycol	000057-55-6	0.457 kg C2H4 / kg
Air	(unspecified)	Propionic acid	000079-09-4	0.15 kg C2H4 / kg
Air	(unspecified)	Propene	000115-07-1	1.123 kg C2H4 / kg
Air	(unspecified)	Propane, 2,2-dimethyl-	000463-82-1	0.173 kg C2H4 / kg
Air	(unspecified)	Propane	000074-98-6	0.176 kg C2H4 / kg
Air	(unspecified)	Propanal	000123-38-6	0.798 kg C2H4 / kg
Air	(unspecified)	Pentane, 3-methyl-	000096-14-0	0.479 kg C2H4 / kg
Air	(unspecified)	Pentane, 2-methyl-	000107-83-5	0.42 kg C2H4 / kg
Air	(unspecified)	Pentane	000109-66-0	0.395 kg C2H4 / kg
Air	(unspecified)	Pentanal	000110-62-3	0.765 kg C2H4 / kg
Air	(unspecified)	p-Xylene	000106-42-3	1.01 kg C2H4 / kg
Air	(unspecified)	Octane	000111-65-9	0.453 kg C2H4 / kg
Air	(unspecified)	o-Xylene	000095-47-6	1.053 kg C2H4 / kg
Air	(unspecified)	Nonane	000111-84-2	0.414 kg C2H4 / kg
Air	(unspecified)	NMVOC ; non-methane volatile organic compounds ; unspecified origin		0.398 kg C2H4 / kg
Air	(unspecified)	Nitrogen oxides	011104-93-1	0.028 kg C2H4 / kg
Air	(unspecified)	Nitrogen dioxide	010102-44-0	0.028 kg C2H4 / kg
Air	(unspecified)	Nitric oxide	010102-43-9	-0.427 kg C2H4 / kg
Air	(unspecified)	Methyl formate	000107-31-3	0.027 kg C2H4 / kg
Air	(unspecified)	Methyl ethyl ketone	000078-93-3	0.373 kg C2H4 / kg
Air	(unspecified)	Methanol	000067-56-1	0.14 kg C2H4 / kg
Air	(unspecified)	Methane, monochloro-, R-40	000074-87-3	0.005 kg C2H4 / kg
Air	(unspecified)	Methane, fossil	000074-82-8	0.006 kg C2H4 / kg
Air	(unspecified)	Methane, dimethoxy-	000109-87-5	0.164 kg C2H4 / kg
Air	(unspecified)	Methane, dichloro-, HCC-30	000075-09-2	0.068 kg C2H4 / kg
Air	(unspecified)	Methane, biogenic	000074-82-8	0.006 kg C2H4 / kg
Air	(unspecified)	Methane	000074-82-8	0.006 kg C2H4 / kg
Air	(unspecified)	m-Xylene	000108-38-3	1.108 kg C2H4 / kg
Air	(unspecified)	Isopropyl acetate	000108-21-4	0.211 kg C2H4 / kg
Air	(unspecified)	Isoprene	000078-79-5	1.092 kg C2H4 / kg
Air	(unspecified)	Isopentane	000078-78-4	0.405 kg C2H4 / kg
Air	(unspecified)	Isobutyraldehyde	000078-84-2	0.514 kg C2H4 / kg
Air	(unspecified)	Isobutene	000115-11-7	0.627 kg C2H4 / kg
Air	(unspecified)	Isobutanol	000078-83-1	0.36 kg C2H4 / kg
Air	(unspecified)	Isobutane	000075-28-5	0.307 kg C2H4 / kg
Air	(unspecified)	Hexane, 3-methyl-	000589-34-4	0.364 kg C2H4 / kg
Air	(unspecified)	Hexane, 2-methyl-	000591-76-4	0.411 kg C2H4 / kg
Air	(unspecified)	Hexane	000110-54-3	0.482 kg C2H4 / kg
Air	(unspecified)	Heptane	000142-82-5	0.494 kg C2H4 / kg
Air	(unspecified)	Formic acid	000064-18-6	0.032 kg C2H4 / kg
Air	(unspecified)	Formaldehyde	000050-00-0	0.519 kg C2H4 / kg
Air	(unspecified)	Ethyne	000074-86-2	0.085 kg C2H4 / kg
Air	(unspecified)	Ethylene glycol monoethyl ether	000110-80-5	0.386 kg C2H4 / kg
Air	(unspecified)	Ethylene glycol	000107-21-1	0.373 kg C2H4 / kg
Air	(unspecified)	Ethyl acetate	000141-78-6	0.209 kg C2H4 / kg
Air	(unspecified)	Ethene, trichloro-	000079-01-6	0.325 kg C2H4 / kg
Air	(unspecified)	Ethene, tetrachloro-	000127-18-4	0.029 kg C2H4 / kg
Air	(unspecified)	Ethene, dichloro- (trans)	000156-60-5	0.392 kg C2H4 / kg
Air	(unspecified)	Ethene, dichloro- (cis)	000156-59-2	0.447 kg C2H4 / kg
Air	(unspecified)	Ethene	000074-85-1	1 kg C2H4 / kg
Air	(unspecified)	Ethanol, 2-methoxy-	000109-86-4	0.307 kg C2H4 / kg
Air	(unspecified)	Ethanol, 2-ethoxy-	000110-80-5	0.386 kg C2H4 / kg
Air	(unspecified)	Ethanol, 2-butoxy-	000111-76-2	0.483 kg C2H4 / kg
Air	(unspecified)	Ethanol	000064-17-5	0.399 kg C2H4 / kg
Air	(unspecified)	Ethane, 1,1,1-trichloro-, HCFC-140	000071-55-6	0.009 kg C2H4 / kg
Air	(unspecified)	Ethane	000074-84-0	0.123 kg C2H4 / kg
Air	(unspecified)	Dodecane	000112-40-3	0.357 kg C2H4 / kg
Air	(unspecified)	Dimethyl ether	000115-10-6	0.189 kg C2H4 / kg
Air	(unspecified)	Dimethyl carbonate	000616-38-6	0.025 kg C2H4 / kg
Air	(unspecified)	Diisopropyl ether	000108-20-3	0.398 kg C2H4 / kg
Air	(unspecified)	Diethyl ketone	000096-22-0	0.414 kg C2H4 / kg
Air	(unspecified)	Diethyl ether	000060-29-7	0.445 kg C2H4 / kg
Air	(unspecified)	Diacetone alcohol	000123-42-2	0.307 kg C2H4 / kg
Air	(unspecified)	Decane	000124-18-5	0.384 kg C2H4 / kg
Air	(unspecified)	Cyclohexanone	000108-94-1	0.299 kg C2H4 / kg
Air	(unspecified)	Cyclohexanol	000108-93-0	0.518 kg C2H4 / kg
Air	(unspecified)	Cyclohexane	000110-82-7	0.29 kg C2H4 / kg
Air	(unspecified)	Cumene	000098-82-8	0.5 kg C2H4 / kg
Air	(unspecified)	Chloroform	000067-66-3	0.023 kg C2H4 / kg
Air	(unspecified)	Carbon monoxide, fossil	000630-08-0	0.027 kg C2H4 / kg
Air	(unspecified)	Carbon monoxide, biogenic	000630-08-0	0.027 kg C2H4 / kg
Air	(unspecified)	Carbon monoxide	000630-08-0	0.027 kg C2H4 / kg
Air	(unspecified)	Butyl acetate	000123-86-4	0.269 kg C2H4 / kg
Air	(unspecified)	Butanol, 3-methyl-2-	000598-75-4	0.406 kg C2H4 / kg
Air	(unspecified)	Butanol, 3-methyl-1-	000123-51-3	0.406 kg C2H4 / kg
Air	(unspecified)	Butanol, 2-methyl-2-	000075-85-4	0.228 kg C2H4 / kg
Air	(unspecified)	Butanol, 2-methyl-1-	000137-32-6	0.489 kg C2H4 / kg
Air	(unspecified)	Butanol	035296-72-1	0.62 kg C2H4 / kg
Air	(unspecified)	Butane, 2,3-dimethyl-	000079-29-8	0.541 kg C2H4 / kg
Air	(unspecified)	Butane, 2,2-dimethyl-	000075-83-2	0.241 kg C2H4 / kg
Air	(unspecified)	Butane	000106-97-8	0.352 kg C2H4 / kg
Air	(unspecified)	Butanal	000123-72-8	0.795 kg C2H4 / kg
Air	(unspecified)	Butadiene	000106-99-0	0.851 kg C2H4 / kg
Air	(unspecified)	Benzene, ethyl-	000100-41-4	0.73 kg C2H4 / kg
Air	(unspecified)	Benzene, 3,5-dimethylethyl-	000934-74-7	1.32 kg C2H4 / kg
Air	(unspecified)	Benzene, 1,3,5-trimethyl-	000108-67-8	1.381 kg C2H4 / kg
Air	(unspecified)	Benzene, 1,2,4-trimethyl-	000095-63-6	1.278 kg C2H4 / kg
Air	(unspecified)	Benzene, 1,2,3-trimethyl-	000526-73-8	1.267 kg C2H4 / kg
Air	(unspecified)	Benzene, 1-propyl-	000103-65-1	0.636 kg C2H4 / kg
Air	(unspecified)	Benzene	000071-43-2	0.218 kg C2H4 / kg
Air	(unspecified)	Benzaldehyde	000100-52-7	-0.092 kg C2H4 / kg
Air	(unspecified)	Alcohol, diacetone	000123-42-2	0.307 kg C2H4 / kg
Air	(unspecified)	Acetone	000067-64-1	0.094 kg C2H4 / kg
Air	(unspecified)	Acetic acid, propyl ester	000109-60-4	0.282 kg C2H4 / kg
Air	(unspecified)	Acetic acid, methyl ester	000079-20-9	0.059 kg C2H4 / kg
Air	(unspecified)	Acetic acid, ethyl ester	000141-78-6	0.209 kg C2H4 / kg
Air	(unspecified)	Acetic acid, butyl ester	000123-86-4	0.269 kg C2H4 / kg
Air	(unspecified)	Acetic acid	000064-19-7	0.097 kg C2H4 / kg
Air	(unspecified)	Acetaldehyde	000075-07-0	0.641 kg C2H4 / kg
Air	(unspecified)	4-Methyl-2-pentanone	000108-10-1	0.49 kg C2H4 / kg
Air	(unspecified)	3-Pentanol	000584-02-1	0.595 kg C2H4 / kg
Air	(unspecified)	3-Methyl-1-butanol	000123-51-3	0.433 kg C2H4 / kg
Air	(unspecified)	3-Hexanone	000589-38-8	0.599 kg C2H4 / kg
Air	(unspecified)	2-Propanol	000067-63-0	0.188 kg C2H4 / kg
Air	(unspecified)	2-Pentene (trans)	000646-04-8	1.117 kg C2H4 / kg
Air	(unspecified)	2-Pentene (cis)	000627-20-3	1.121 kg C2H4 / kg
Air	(unspecified)	2-Pentanone	000107-87-9	0.548 kg C2H4 / kg
Air	(unspecified)	2-Methyl pentane	000107-83-5	0.42 kg C2H4 / kg
Air	(unspecified)	2-Methyl-2-butene	000513-35-9	0.842 kg C2H4 / kg
Air	(unspecified)	2-Methyl-1-propanol	000078-83-1	0.36 kg C2H4 / kg
Air	(unspecified)	2-Hexene (trans)	004050-45-7	1.073 kg C2H4 / kg
Air	(unspecified)	2-Hexene (cis)	007688-21-3	1.069 kg C2H4 / kg
Air	(unspecified)	2-Hexanone	000591-78-6	0.572 kg C2H4 / kg
Air	(unspecified)	2-Butene, 2-methyl-	000513-35-9	0.842 kg C2H4 / kg
Air	(unspecified)	2-Butene (trans)	000624-64-6	1.132 kg C2H4 / kg
Air	(unspecified)	2-Butene (cis)	000590-18-1	1.146 kg C2H4 / kg
Air	(unspecified)	2-Butanone, 3,3-dimethyl-	000075-97-8	0.323 kg C2H4 / kg
Air	(unspecified)	2-Butanone, 3-methyl-	000563-80-4	0.364 kg C2H4 / kg
Air	(unspecified)	2-Butanol	000078-92-2	0.4 kg C2H4 / kg
Air	(unspecified)	1-Propanol	000071-23-8	0.561 kg C2H4 / kg
Air	(unspecified)	1-Pentene	000109-67-1	0.977 kg C2H4 / kg
Air	(unspecified)	1-Hexene	000592-41-6	0.874 kg C2H4 / kg
Air	(unspecified)	1-Butene, 3-methyl-	000563-45-1	0.671 kg C2H4 / kg
Air	(unspecified)	1-Butene, 2-methyl-	000563-46-2	0.771 kg C2H4 / kg
Air	(unspecified)	1-Butene	000106-98-9	1.079 kg C2H4 / kg
Air	(unspecified)	1-Butanol	000071-36-3	0.62 kg C2H4 / kg

Eutrophication	**kg PO4--- eq**			
Soil	(unspecified)	Phosphorus, total		3.06 kg PO4--- eq / kg
Water	(unspecified)	Phosphorus, total		3.06 kg PO4--- eq / kg
Air	(unspecified)	Phosphorus, total		3.06 kg PO4--- eq / kg
Soil	industrial	Phosphorus pentoxide	001314-56-3	1.34 kg PO4--- eq / kg
Soil	agricultural	Phosphorus pentoxide	001314-56-3	1.34 kg PO4--- eq / kg
Water	ocean	Phosphorus pentoxide	001314-56-3	1.34 kg PO4--- eq / kg
Water	(unspecified)	Phosphorus pentoxide	001314-56-3	1.34 kg PO4--- eq / kg
Air	(unspecified)	Phosphorus pentoxide	001314-56-3	1.34 kg PO4--- eq / kg
Soil	industrial	Phosphorus	007723-14-0	3.06 kg PO4--- eq / kg
Soil	agricultural	Phosphorus	007723-14-0	3.06 kg PO4--- eq / kg
Water	ocean	Phosphorus	007723-14-0	3.06 kg PO4--- eq / kg
Water	(unspecified)	Phosphorus	007723-14-0	3.06 kg PO4--- eq / kg
Air	(unspecified)	Phosphorus	007723-14-0	3.06 kg PO4--- eq / kg
Soil	industrial	Phosphoric acid	007664-38-2	0.97 kg PO4--- eq / kg
Soil	agricultural	Phosphoric acid	007664-38-2	0.97 kg PO4--- eq / kg
Water	ocean	Phosphoric acid	007664-38-2	0.97 kg PO4--- eq / kg
Water	(unspecified)	Phosphoric acid	007664-38-2	0.97 kg PO4--- eq / kg
Air	(unspecified)	Phosphoric acid	007664-38-2	0.97 kg PO4--- eq / kg
Soil	industrial	Phosphate	014265-44-2	1 kg PO4--- eq / kg
Soil	agricultural	Phosphate	014265-44-2	1 kg PO4--- eq / kg
Water	ocean	Phosphate	014265-44-2	1 kg PO4--- eq / kg
Water	(unspecified)	Phosphate	014265-44-2	1 kg PO4--- eq / kg
Air	(unspecified)	Phosphate	014265-44-2	1 kg PO4--- eq / kg
Soil	(unspecified)	Nitrogen, total		0.42 kg PO4--- eq / kg
Soil	(unspecified)	Nitrogen oxides	011104-93-1	0.13 kg PO4--- eq / kg
Air	low. pop.	Nitrogen oxides	011104-93-1	0.13 kg PO4--- eq / kg
Air	(unspecified)	Nitrogen oxides	011104-93-1	0.13 kg PO4--- eq / kg
Air	(unspecified)	Nitrogen dioxide	010102-44-0	0.13 kg PO4--- eq / kg
Soil	industrial	Nitrogen	007727-37-9	0.42 kg PO4--- eq / kg
Soil	agricultural	Nitrogen	007727-37-9	0.42 kg PO4--- eq / kg
Water	ocean	Nitrogen	007727-37-9	0.42 kg PO4--- eq / kg
Water	(unspecified)	Nitrogen	007727-37-9	0.42 kg PO4--- eq / kg
Air	(unspecified)	Nitrogen	007727-37-9	0.42 kg PO4--- eq / kg
Water	ocean	Nitrite	014797-65-0	0.1 kg PO4--- eq / kg
Water	(unspecified)	Nitrite	014797-65-0	0.1 kg PO4--- eq / kg
Air	(unspecified)	Nitric oxide	010102-43-9	0.2 kg PO4--- eq / kg
Soil	industrial	Nitric acid	007697-37-2	0.1 kg PO4--- eq / kg
Soil	agricultural	Nitric acid	007697-37-2	0.1 kg PO4--- eq / kg
Water	ocean	Nitric acid	007697-37-2	0.1 kg PO4--- eq / kg
Water	(unspecified)	Nitric acid	007697-37-2	0.1 kg PO4--- eq / kg
Air	(unspecified)	Nitric acid	007697-37-2	0.1 kg PO4--- eq / kg
Soil	industrial	Nitrate	014797-55-8	0.1 kg PO4--- eq / kg
Soil	agricultural	Nitrate	014797-55-8	0.1 kg PO4--- eq / kg
Water	ocean	Nitrate	014797-55-8	0.1 kg PO4--- eq / kg
Water	(unspecified)	Nitrate	014797-55-8	0.1 kg PO4--- eq / kg
Air	(unspecified)	Nitrate	014797-55-8	0.1 kg PO4--- eq / kg
Water	ocean	COD, Chemical Oxygen Demand		0.022 kg PO4--- eq / kg
Water	(unspecified)	COD, Chemical Oxygen Demand		0.022 kg PO4--- eq / kg
Soil	industrial	Ammonium, ion	014798-03-9	0.33 kg PO4--- eq / kg
Soil	agricultural	Ammonium, ion	014798-03-9	0.33 kg PO4--- eq / kg
Water	ocean	Ammonium, ion	014798-03-9	0.33 kg PO4--- eq / kg
Water	(unspecified)	Ammonium, ion	014798-03-9	0.33 kg PO4--- eq / kg
Air	(unspecified)	Ammonium, ion	014798-03-9	0.33 kg PO4--- eq / kg
Soil	(unspecified)	Ammonium nitrate	006484-52-2	0.074 kg PO4--- eq / kg
Air	(unspecified)	Ammonium nitrate	006484-52-2	0.074 kg PO4--- eq / kg
Air	(unspecified)	Ammonium carbonate	000506-87-6	0.12 kg PO4--- eq / kg
Soil	industrial	Ammonia	007664-41-7	0.35 kg PO4--- eq / kg
Soil	agricultural	Ammonia	007664-41-7	0.35 kg PO4--- eq / kg
Water	ocean	Ammonia	007664-41-7	0.35 kg PO4--- eq / kg
Water	(unspecified)	Ammonia	007664-41-7	0.35 kg PO4--- eq / kg
Air	(unspecified)	Ammonia	007664-41-7	0.35 kg PO4--- eq / kg

Carcinogens	**DALY**				
Soil	(unspecified)	Trifluralin	001582-09-8	6.89E-05	DALY / kg
Water	(unspecified)	Trifluralin	001582-09-8	7.93E-05	DALY / kg
Air	(unspecified)	Trifluralin	001582-09-8	1.1E-07	DALY / kg
Soil	(unspecified)	Styrene	000100-42-5	2.09E-08	DALY / kg
Water	(unspecified)	Styrene	000100-42-5	1.22E-06	DALY / kg
Air	(unspecified)	Styrene	000100-42-5	2.44E-08	DALY / kg
Water	(unspecified)	Sodium dichromate	010588-01-9	3.28E-07	DALY / kg
Air	(unspecified)	Sodium dichromate	010588-01-9	0.00232	DALY / kg
Soil	(unspecified)	Propylene oxide	000075-56-9	0.00014	DALY / kg
Water	(unspecified)	Propylene oxide	000075-56-9	1.74E-05	DALY / kg
Air	(unspecified)	Propylene oxide	000075-56-9	1.17E-05	DALY / kg
Soil	(unspecified)	Polychlorinated biphenyls	001336-36-3	0.0204	DALY / kg
Water	(unspecified)	Polychlorinated biphenyls	001336-36-3	0.0391	DALY / kg
Air	(unspecified)	Polychlorinated biphenyls	001336-36-3	0.00197	DALY / kg
Soil	(unspecified)	Phthalate, dioctyl-	000117-81-7	3.18E-07	DALY / kg
Water	(unspecified)	Phthalate, dioctyl-	000117-81-7	0.000664	DALY / kg
Air	(unspecified)	Phthalate, dioctyl-	000117-81-7	3.38E-05	DALY / kg
Soil	(unspecified)	Phthalate, dibutyl-	000084-74-2	0.000006	DALY / kg
Water	(unspecified)	Phthalate, dibutyl-	000084-74-2	0.0534	DALY / kg
Air	(unspecified)	Phthalate, dibutyl-	000084-74-2	0.00343	DALY / kg
Soil	(unspecified)	Phenol, pentachloro-	000087-86-5	1.26E-05	DALY / kg
Water	(unspecified)	Phenol, pentachloro-	000087-86-5	0.0229	DALY / kg
Air	(unspecified)	Phenol, pentachloro-	000087-86-5	0.00721	DALY / kg
Soil	(unspecified)	Phenol, 2,4,6-trichloro-	000088-06-2	2.76E-06	DALY / kg
Water	(unspecified)	Phenol, 2,4,6-trichloro-	000088-06-2	1.05E-05	DALY / kg
Air	(unspecified)	Phenol, 2,4,6-trichloro-	000088-06-2	2.05E-06	DALY / kg
Air	(unspecified)	Particulates, diesel soot		9.78E-06	DALY / kg
Water	(unspecified)	PAH, polycyclic aromatic hydrocarbons	130498-29-2	0.0026	DALY / kg
Air	(unspecified)	PAH, polycyclic aromatic hydrocarbons	130498-29-2	0.00017	DALY / kg
Water	(unspecified)	Nickel, ion	014701-22-5	6.91E-11	DALY / kg
Soil	(unspecified)	Nickel subsulfide	012035-72-2	0.0127	DALY / kg
Water	(unspecified)	Nickel subsulfide	012035-72-2	0.00502	DALY / kg
Air	(unspecified)	Nickel subsulfide	012035-72-2	0.0948	DALY / kg
Soil	(unspecified)	Nickel refinery dust		0.00637	DALY / kg
Water	(unspecified)	Nickel refinery dust		0.01	DALY / kg
Air	(unspecified)	Nickel refinery dust		0.0474	DALY / kg
Soil	(unspecified)	Nickel	007440-02-0	4.21E-09	DALY / kg
Air	(unspecified)	Nickel	007440-02-0	4.29E-05	DALY / kg
Soil	(unspecified)	Methane, tetrachloro-, CFC-10	000056-23-5	0.0399	DALY / kg
Water	(unspecified)	Methane, tetrachloro-, CFC-10	000056-23-5	0.000829	DALY / kg
Air	(unspecified)	Methane, tetrachloro-, CFC-10	000056-23-5	0.000838	DALY / kg
Soil	(unspecified)	Methane, monochloro-, R-40	000074-87-3	0.000558	DALY / kg
Water	(unspecified)	Methane, monochloro-, R-40	000074-87-3	1.78E-05	DALY / kg
Air	(unspecified)	Methane, monochloro-, R-40	000074-87-3	1.83E-05	DALY / kg
Soil	(unspecified)	Methane, dichloro-, HCC-30	000075-09-2	5.99E-06	DALY / kg
Water	(unspecified)	Methane, dichloro-, HCC-30	000075-09-2	4.79E-07	DALY / kg
Air	(unspecified)	Methane, dichloro-, HCC-30	000075-09-2	4.36E-07	DALY / kg
Soil	(unspecified)	Methane, bromodichloro-	000075-27-4	7.82E-05	DALY / kg
Water	(unspecified)	Methane, bromodichloro-	000075-27-4	9.36E-06	DALY / kg
Air	(unspecified)	Methane, bromodichloro-	000075-27-4	8.76E-06	DALY / kg
Air	(unspecified)	Metals, unspecified		0.000697	DALY / kg
Water	(unspecified)	Metallic ions, unspecified		4.27E-05	DALY / kg
Soil	(unspecified)	Lindane, beta-	000319-85-7	0.00736	DALY / kg
Water	(unspecified)	Lindane, beta-	000319-85-7	0.00575	DALY / kg
Air	(unspecified)	Lindane, beta-	000319-85-7	9.99E-05	DALY / kg
Soil	(unspecified)	Lindane, alpha-	000319-84-6	0.0232	DALY / kg
Water	(unspecified)	Lindane, alpha-	000319-84-6	0.00685	DALY / kg
Air	(unspecified)	Lindane, alpha-	000319-84-6	0.0003	DALY / kg
Soil	(unspecified)	Lindane	000058-89-9	0.00864	DALY / kg
Water	(unspecified)	Lindane	000058-89-9	0.00416	DALY / kg
Air	(unspecified)	Lindane	000058-89-9	0.000349	DALY / kg
Air	(unspecified)	Heavy metals, unspecified		0.000697	DALY / kg
Soil	(unspecified)	Formaldehyde	000050-00-0	1.83E-06	DALY / kg
Water	(unspecified)	Formaldehyde	000050-00-0	4.97E-06	DALY / kg
Air	(unspecified)	Formaldehyde	000050-00-0	9.91E-07	DALY / kg
Soil	(unspecified)	Ethylene oxide	000075-21-8	0.00238	DALY / kg
Water	(unspecified)	Ethylene oxide	000075-21-8	0.000139	DALY / kg
Air	(unspecified)	Ethylene oxide	000075-21-8	0.000183	DALY / kg
Soil	(unspecified)	Ethene, trichloro-	000079-01-6	3.22E-07	DALY / kg
Water	(unspecified)	Ethene, trichloro-	000079-01-6	7.97E-08	DALY / kg
Air	(unspecified)	Ethene, trichloro-	000079-01-6	7.95E-08	DALY / kg
Soil	(unspecified)	Ethene, tetrachloro-	000127-18-4	0.000006	DALY / kg
Water	(unspecified)	Ethene, tetrachloro-	000127-18-4	4.72E-07	DALY / kg
Air	(unspecified)	Ethene, tetrachloro-	000127-18-4	4.82E-07	DALY / kg
Soil	(unspecified)	Ethene, chloro-	000075-01-4	7.67E-07	DALY / kg
Water	(unspecified)	Ethene, chloro-	000075-01-4	2.84E-07	DALY / kg
Air	(unspecified)	Ethene, chloro-	000075-01-4	2.09E-07	DALY / kg
Soil	(unspecified)	Ethene, 1,1-dichloro-	000075-35-4	5.57E-06	DALY / kg
Water	(unspecified)	Ethene, 1,1-dichloro-	000075-35-4	5.88E-05	DALY / kg
Air	(unspecified)	Ethene, 1,1-dichloro-	000075-35-4	3.43E-06	DALY / kg
Soil	(unspecified)	Ethane, hexachloro-	000067-72-1	0.000526	DALY / kg
Water	(unspecified)	Ethane, hexachloro-	000067-72-1	2.12E-05	DALY / kg
Air	(unspecified)	Ethane, hexachloro-	000067-72-1	1.99E-05	DALY / kg
Soil	(unspecified)	Ethane, 1,2-dichloro-	000107-06-2	0.000458	DALY / kg
Water	(unspecified)	Ethane, 1,2-dichloro-	000107-06-2	2.98E-05	DALY / kg
Air	(unspecified)	Ethane, 1,2-dichloro-	000107-06-2	2.98E-05	DALY / kg
Soil	(unspecified)	Ethane, 1,2-dibromo-	000106-93-4	0.00381	DALY / kg
Water	(unspecified)	Ethane, 1,2-dibromo-	000106-93-4	0.00124	DALY / kg
Air	(unspecified)	Ethane, 1,2-dibromo-	000106-93-4	0.00026	DALY / kg
Soil	(unspecified)	Ethane, 1,1,2,2-tetrachloro-	000079-34-5	0.00754	DALY / kg
Water	(unspecified)	Ethane, 1,1,2,2-tetrachloro-	000079-34-5	0.000278	DALY / kg
Air	(unspecified)	Ethane, 1,1,2,2-tetrachloro-	000079-34-5	0.000286	DALY / kg
Soil	(unspecified)	Ethane, 1,1,2-trichloro-	000079-00-5	0.000124	DALY / kg
Water	(unspecified)	Ethane, 1,1,2-trichloro-	000079-00-5	1.23E-05	DALY / kg
Air	(unspecified)	Ethane, 1,1,2-trichloro-	000079-00-5	0.000011	DALY / kg
Soil	(unspecified)	Ethane, 1,1,1,2-tetrachloro-	000630-20-6	0.00109	DALY / kg
Water	(unspecified)	Ethane, 1,1,1,2-tetrachloro-	000630-20-6	3.66E-05	DALY / kg
Air	(unspecified)	Ethane, 1,1,1,2-tetrachloro-	000630-20-6	3.72E-05	DALY / kg
Soil	(unspecified)	Epichlorohydrin	000106-89-8	1.3E-06	DALY / kg
Water	(unspecified)	Epichlorohydrin	000106-89-8	9.9E-07	DALY / kg
Air	(unspecified)	Epichlorohydrin	000106-89-8	3.02E-07	DALY / kg
Soil	(unspecified)	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin		7.06	DALY / kg
Water	(unspecified)	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin		2020	DALY / kg
Air	(unspecified)	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin		179	DALY / kg
Water	(unspecified)	Dioxane, 1,4-	000123-91-1	9.21E-07	DALY / kg
Air	(unspecified)	Dioxane, 1,4-	000123-91-1	1.39E-07	DALY / kg
Soil	(unspecified)	Dieldrin	000060-57-1	417	DALY / kg
Water	(unspecified)	Dieldrin	000060-57-1	97.5	DALY / kg
Air	(unspecified)	Dieldrin	000060-57-1	27	DALY / kg
Water	(unspecified)	Dichromate		3.98E-10	DALY / kg
Soil	(unspecified)	Dichlorvos	000062-73-7	2.25E-05	DALY / kg
Water	(unspecified)	Dichlorvos	000062-73-7	1.17E-05	DALY / kg
Air	(unspecified)	Dichlorvos	000062-73-7	3.15E-05	DALY / kg
Soil	(unspecified)	Dibenz(a,h)anthracene	000053-70-3	24.4	DALY / kg
Water	(unspecified)	Dibenz(a,h)anthracene	000053-70-3	40.7	DALY / kg
Air	(unspecified)	Dibenz(a,h)anthracene	000053-70-3	31	DALY / kg
Soil	(unspecified)	Chromium VI	018540-29-9	3.68E-07	DALY / kg
Water	(unspecified)	Chromium VI	018540-29-9	8.26E-10	DALY / kg
Air	(unspecified)	Chromium VI	018540-29-9	0.00584	DALY / kg
Water	(unspecified)	Cholanthrene, 3-methyl-	000056-49-5	37.2	DALY / kg
Air	(unspecified)	Cholanthrene, 3-methyl-	000056-49-5	0.167	DALY / kg
Soil	(unspecified)	Chloroform	000067-66-3	4.12E-06	DALY / kg
Water	(unspecified)	Chloroform	000067-66-3	0.000026	DALY / kg
Air	(unspecified)	Chloroform	000067-66-3	2.63E-05	DALY / kg
Water	(unspecified)	Cadmium, ion	022537-48-0	0.0712	DALY / kg
Soil	agricultural	Cadmium	007440-43-9	2.17	DALY / kg
Soil	(unspecified)	Cadmium	007440-43-9	0.00398	DALY / kg
Air	(unspecified)	Cadmium	007440-43-9	0.135	DALY / kg
Soil	(unspecified)	Butadiene, hexachloro-	000087-68-3	0.000856	DALY / kg
Water	(unspecified)	Butadiene, hexachloro-	000087-68-3	0.000108	DALY / kg
Air	(unspecified)	Butadiene, hexachloro-	000087-68-3	0.000043	DALY / kg
Soil	(unspecified)	Butadiene	000106-99-0	0.000012	DALY / kg
Water	(unspecified)	Butadiene	000106-99-0	0.000337	DALY / kg
Air	(unspecified)	Butadiene	000106-99-0	1.58E-05	DALY / kg
Soil	(unspecified)	Bis(chloromethyl)ether	000542-88-1	0.0168	DALY / kg
Water	(unspecified)	Bis(chloromethyl)ether	000542-88-1	0.0154	DALY / kg
Air	(unspecified)	Bis(chloromethyl)ether	000542-88-1	0.00748	DALY / kg
Soil	(unspecified)	Bis(2-chloroethyl)ether	000111-44-4	8.29E-05	DALY / kg
Water	(unspecified)	Bis(2-chloroethyl)ether	000111-44-4	0.000161	DALY / kg
Air	(unspecified)	Bis(2-chloroethyl)ether	000111-44-4	4.03E-05	DALY / kg
Soil	(unspecified)	Benzyl chloride	000100-44-7	4.16E-05	DALY / kg
Water	(unspecified)	Benzyl chloride	000100-44-7	1.98E-05	DALY / kg
Air	(unspecified)	Benzyl chloride	000100-44-7	1.04E-05	DALY / kg
Soil	(unspecified)	Benzotrichloride	000098-07-7	0.132	DALY / kg
Water	(unspecified)	Benzotrichloride	000098-07-7	0.00946	DALY / kg
Air	(unspecified)	Benzotrichloride	000098-07-7	0.0066	DALY / kg
Soil	(unspecified)	Benzo(a)pyrene	000050-32-8	0.00206	DALY / kg
Water	(unspecified)	Benzo(a)pyrene	000050-32-8	2.99	DALY / kg
Air	(unspecified)	Benzo(a)pyrene	000050-32-8	0.00398	DALY / kg
Soil	(unspecified)	Benzo(a)anthracene	000056-55-3	0.16	DALY / kg
Water	(unspecified)	Benzo(a)anthracene	000056-55-3	0.658	DALY / kg
Air	(unspecified)	Benzo(a)anthracene	000056-55-3	0.0586	DALY / kg
Soil	(unspecified)	Benzene, hexachloro-	000118-74-1	0.147	DALY / kg
Water	(unspecified)	Benzene, hexachloro-	000118-74-1	0.125	DALY / kg
Air	(unspecified)	Benzene, hexachloro-	000118-74-1	0.0825	DALY / kg
Soil	(unspecified)	Benzene	000071-43-2	1.33E-05	DALY / kg

Land use	Ha a		
Raw	land	Occupation, water bodies, artificial	1 Ha a / ha a
Raw	land	Occupation, urban, green areas	1 Ha a / ha a
Raw	land	Occupation, urban, discontinuously built	1 Ha a / ha a
Raw	land	Occupation, urban, continuously built	1 Ha a / ha a
Raw	land	Occupation, unknown	1 Ha a / ha a
Raw	(unspecified)	Occupation, tropical rain forest	1 Ha a / ha a
Raw	(unspecified)	Occupation, traffic area, road network	1 Ha a / ha a
Raw	(unspecified)	Occupation, traffic area, road embankment	1 Ha a / ha a
Raw	(unspecified)	Occupation, traffic area, rail network	1 Ha a / ha a
Raw	(unspecified)	Occupation, traffic area, rail embankment	1 Ha a / ha a
Raw	land	Occupation, traffic area	1 Ha a / ha a
Raw	(unspecified)	Occupation, shrub land, sclerophyllous	1 Ha a / ha a
Raw	(unspecified)	Occupation, pipelines	1 Ha a / ha a
Raw	(unspecified)	Occupation, permanent crop, vine, intensive	1 Ha a / ha a
Raw	(unspecified)	Occupation, permanent crop, vine, extensive	1 Ha a / ha a
Raw	(unspecified)	Occupation, permanent crop, vine	1 Ha a / ha a
Raw	(unspecified)	Occupation, permanent crop, fruit, intensive	1 Ha a / ha a
Raw	(unspecified)	Occupation, permanent crop, fruit, extensive	1 Ha a / ha a
Raw	(unspecified)	Occupation, permanent crop, fruit	1 Ha a / ha a
Raw	(unspecified)	Occupation, permanent crop	1 Ha a / ha a
Raw	land	Occupation, pasture and meadow, organic	1 Ha a / ha a
Raw	land	Occupation, pasture and meadow, intensive	1 Ha a / ha a
Raw	land	Occupation, pasture and meadow, extensive	1 Ha a / ha a
Raw	(unspecified)	Occupation, pasture and meadow	1 Ha a / ha a
Raw	(unspecified)	Occupation, oil and gas extraction site	1 Ha a / ha a
Raw	land	Occupation, mineral extraction site	1 Ha a / ha a
Raw	(unspecified)	Occupation, industrial area, vegetation	1 Ha a / ha a
Raw	(unspecified)	Occupation, industrial area, built up	1 Ha a / ha a
Raw	(unspecified)	Occupation, industrial area, benthos	1 Ha a / ha a
Raw	land	Occupation, industrial area	1 Ha a / ha a
Raw	(unspecified)	Occupation, heterogeneous, agricultural	1 Ha a / ha a
Raw	land	Occupation, forest, intensive, short-cycle	1 Ha a / ha a
Raw	land	Occupation, forest, intensive, normal	1 Ha a / ha a
Raw	land	Occupation, forest, intensive, clear-cutting	1 Ha a / ha a
Raw	land	Occupation, forest, intensive	1 Ha a / ha a
Raw	land	Occupation, forest, extensive	1 Ha a / ha a
Raw	land	Occupation, forest	1 Ha a / ha a
Raw	(unspecified)	Occupation, dump site, radioactive, low-medium	1 Ha a / ha a
Raw	(unspecified)	Occupation, dump site, radioactive, high	1 Ha a / ha a
Raw	(unspecified)	Occupation, dump site, radioactive	1 Ha a / ha a
Raw	(unspecified)	Occupation, dump site, benthos	1 Ha a / ha a
Raw	land	Occupation, dump site	1 Ha a / ha a
Raw	(unspecified)	Occupation, construction site	1 Ha a / ha a
Raw	land	Occupation, arable, organic	1 Ha a / ha a
Raw	(unspecified)	Occupation, arable, non-irrigated, monotone-intensive	1 Ha a / ha a
Raw	land	Occupation, arable, non-irrigated, diverse-intensive	1 Ha a / ha a
Raw	(unspecified)	Occupation, arable, non-irrigated	1 Ha a / ha a
Raw	land	Occupation, arable, intensive	1 Ha a / ha a
Raw	land	Occupation, arable	1 Ha a / ha a

Water Use	**KL H2O**				
Raw	(unspecified)	Water, well, in ground /kg		1	KL H2O / tonne
Raw	(unspecified)	Water, unspecified natural origin/kg	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, unspecified natural origin /kg		1	KL H2O / tonne
Raw	(unspecified)	Water, surface		1	KL H2O / tonne
Raw	(unspecified)	Water, stormwater		1	KL H2O / tonne
Raw	(unspecified)	Water, process/kg		1	KL H2O / tonne
Raw	(unspecified)	Water, process, well, in ground	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, process, unspecified natural origin/kg	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, process, surface	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, process, salt, ocean	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, process, river		1	KL H2O / tonne
Raw	(unspecified)	Water, process, drinking	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, drinking		1	KL H2O / tonne
Raw	(unspecified)	Water, cooling/kg		1	KL H2O / tonne
Raw	(unspecified)	Water, cooling, well, in ground	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, cooling, unspecified/kg		1	KL H2O / tonne
Raw	(unspecified)	Water, cooling, unspecified natural origin/kg	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, cooling, surface	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, cooling, salt, ocean	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, cooling, river		1	KL H2O / tonne
Raw	(unspecified)	Water, cooling, drinking	007732-18-5	1	KL H2O / tonne
Raw	(unspecified)	Water, well, in ground/m3	007732-18-5	1	KL H2O / m3
Raw	(unspecified)	Water, well, in ground	007732-18-5	1	KL H2O / m3
Raw	(unspecified)	Water, unspecified natural origin/m3	007732-18-5	1	KL H2O / m3
Raw	(unspecified)	Water, river	007732-18-5	1	KL H2O / m3
Raw	(unspecified)	Water, reticulated supply		1	KL H2O / m3
Raw	(unspecified)	Water, process/m3		1	KL H2O / m3
Raw	(unspecified)	Water, process, unspecified natural origin/m3	007732-18-5	1	KL H2O / m3
Raw	(unspecified)	Water, process and cooling, unspecified natural origin	007732-18-5	1	KL H2O / m3
Raw	(unspecified)	Water, process		1	KL H2O / m3
Raw	(unspecified)	Water, mining, unspecified natural origin/m3		1	KL H2O / m3
Raw	(unspecified)	Water, lake	007732-18-5	1	KL H2O / m3
Raw	(unspecified)	Water, from Victorian catchments	007732-18-5	1	KL H2O / m3
Raw	(unspecified)	Water, fresh	007732-18-5	1	KL H2O / m3
Raw	(unspecified)	Water, cooling/m3		1	KL H2O / m3
Raw	(unspecified)	Water, cooling, unspecified natural origin/m3	007732-18-5	1	KL H2O / m3
Raw	(unspecified)	Water, cooling		1	KL H2O / m3
Solid waste	**kg**				
Waste	(unspecified)	Wood and wood waste		1	kg / tonne
Waste	(unspecified)	Zinc waste		1	kg / kg
Waste	(unspecified)	Zeolite waste		1	kg / kg
Waste	(unspecified)	Wood, sawdust		1	kg / kg
Waste	(unspecified)	Wood waste		1	kg / kg
Waste	(unspecified)	Wood ashes		1	kg / kg
Waste	(unspecified)	Welding dust		1	kg / kg
Waste	(unspecified)	Waste, unspecified		1	kg / kg
Waste	(unspecified)	Waste, toxic		1	kg / kg
Waste	(unspecified)	Waste, to incineration		1	kg / kg
Waste	(unspecified)	Waste, solid		1	kg / kg
Waste	(unspecified)	Waste, sludge		1	kg / kg
Waste	(unspecified)	Waste, Shedder dust		1	kg / kg
Waste	(unspecified)	Waste, nuclear, unspecified/kg		1	kg / kg
Waste	(unspecified)	Waste, limestone		1	kg / kg
Waste	(unspecified)	Waste, inorganic		1	kg / kg
Waste	(unspecified)	Waste, Inert		1	kg / kg
Waste	(unspecified)	Waste, industrial		1	kg / kg
Waste	(unspecified)	Waste, household		1	kg / kg
Waste	(unspecified)	Waste, from incinerator		1	kg / kg
Waste	(unspecified)	Waste, from drilling, unspecified		1	kg / kg
Waste	(unspecified)	Waste, from construction		1	kg / kg
Waste	(unspecified)	Waste, fly ash		1	kg / kg
Waste	(unspecified)	Waste, final, inert		1	kg / kg
Waste	(unspecified)	Waste to recycling		1	kg / kg
Waste	(unspecified)	Waste in inert landfill		1	kg / kg
Waste	(unspecified)	Waste in incineration		1	kg / kg
Waste	(unspecified)	Waste in bioactive landfill		1	kg / kg
Waste	(unspecified)	Tinder from rolling drum		1	kg / kg
Waste	(unspecified)	Tin waste		1	kg / kg
Waste	(unspecified)	Tails		1	kg / kg
Waste	(unspecified)	Stones and rubble		1	kg / kg
Waste	(unspecified)	Steel waste		1	kg / kg
Waste	(unspecified)	Soot		1	kg / kg
Waste	(unspecified)	Slags and ashes		1	kg / kg
Waste	(unspecified)	Slags		1	kg / kg
Waste	(unspecified)	Residues		1	kg / kg
Waste	(unspecified)	Rejects, corrugated cardboard		1	kg / kg
Waste	(unspecified)	Rejects		1	kg / kg
Waste	(unspecified)	Refinery sludge		1	kg / kg
Waste	(unspecified)	Propylene glycol waste		1	kg / kg
Waste	(unspecified)	Production waste, not inert		1	kg / kg
Waste	(unspecified)	Production waste		1	kg / kg
Waste	(unspecified)	Process waste		1	kg / kg
Waste	(unspecified)	Printed circuitboards waste		1	kg / kg
Waste	(unspecified)	Polyvinyl chloride waste		1	kg / kg
Waste	(unspecified)	Polystyrene waste		1	kg / kg
Waste	(unspecified)	Polyethylene waste		1	kg / kg
Waste	(unspecified)	Plastic waste		1	kg / kg
Waste	(unspecified)	Photovoltaic/EVA cell waste		1	kg / kg
Waste	(unspecified)	Photovoltaic production waste		1	kg / kg
Waste	(unspecified)	Photovoltaic panel waste		1	kg / kg
Waste	(unspecified)	Photovoltaic cell waste		1	kg / kg
Waste	(unspecified)	Paint waste		1	kg / kg
Waste	(unspecified)	Packaging waste, wood		1	kg / kg
Waste	(unspecified)	Packaging waste, unspecified		1	kg / kg
Waste	(unspecified)	Packaging waste, steel		1	kg / kg
Waste	(unspecified)	Packaging waste, plastic		1	kg / kg
Waste	(unspecified)	Packaging waste, paper and board		1	kg / kg
Waste	(unspecified)	Oil waste		1	kg / kg
Waste	(unspecified)	Oil separator sludge		1	kg / kg
Waste	(unspecified)	non magenetic fines		1	kg / kg
Waste	(unspecified)	Neutralized Acid Effluent		1	kg / kg
Waste	(unspecified)	Monasite		1	kg / kg
Waste	(unspecified)	Mineral waste, from mining		1	kg / kg
Waste	(unspecified)	Mineral waste		1	kg / kg
Waste	(unspecified)	Metal waste		1	kg / kg
Waste	(unspecified)	Limestone waste		1	kg / kg
Waste	(unspecified)	limestone		1	kg / kg
Waste	(unspecified)	Light bulb waste		1	kg / kg
Waste	(unspecified)	jarosite		1	kg / kg
Waste	(unspecified)	Iron waste		1	kg / kg
Waste	(unspecified)	Ion exchanger sludge		1	kg / kg
Waste	(unspecified)	gypsum		1	kg / kg
Waste	(unspecified)	Glass waste		1	kg / kg
Waste	(unspecified)	Gas pipe waste		1	kg / kg
Waste	(unspecified)	Fly ash		1	kg / kg
Waste	(unspecified)	Fluoride waste		1	kg / kg
Waste	(unspecified)	Electrostatic filter dust		1	kg / kg
Waste	(unspecified)	Electronic waste		1	kg / kg
Waste	(unspecified)	E-saving bulb waste		1	kg / kg
Waste	(unspecified)	E-saving bulb plastic waste		1	kg / kg
Waste	(unspecified)	Dust, unspecified		1	kg / kg
Waste	(unspecified)	Dust, break-out		1	kg / kg
Waste	(unspecified)	Dross for recycling		1	kg / kg
Waste	(unspecified)	Dross		1	kg / kg
Waste	(unspecified)	Copper waste		1	kg / kg
Waste	(unspecified)	Copper absorbent waste		1	kg / kg
Waste	(unspecified)	Construction waste		1	kg / kg
Waste	(unspecified)	Coal tailings		1	kg / kg
Waste	(unspecified)	Coal ash		1	kg / kg
Waste	(unspecified)	Chromium waste		1	kg / kg
Waste	(unspecified)	Chemical waste, unspecified		1	kg / kg
Waste	(unspecified)	Chemical waste, regulated		1	kg / kg
Waste	(unspecified)	Chemical waste, inert		1	kg / kg
Waste	(unspecified)	Cathode loss		1	kg / kg
Waste	(unspecified)	Cathode iron ingots waste		1	kg / kg
Waste	(unspecified)	Catalyst waste		1	kg / kg
Waste	(unspecified)	Carton waste		1	kg / kg
Waste	(unspecified)	Cardboard waste		1	kg / kg
Waste	(unspecified)	cardboard		1	kg / kg
Waste	(unspecified)	Calcium fluoride waste		1	kg / kg
Waste	(unspecified)	Bulk waste, unspecified		1	kg / kg
Waste	(unspecified)	Bitumen waste		1	kg / kg
Waste	(unspecified)	Bilge oil		1	kg / kg
Waste	(unspecified)	Asphalt waste		1	kg / kg
Waste	(unspecified)	ash		1	kg / kg
Waste	(unspecified)	Asbestos		1	kg / kg
Waste	(unspecified)	Aluminium waste		1	kg / kg

Fossil fuels	**MJ surplus**				
Raw	(unspecified)	Energy, from oil		0.083	MJ surplus / MJ
Raw	(unspecified)	Energy, from liquified petroleum gas, feedstock		0.089	MJ surplus / MJ
Raw	(unspecified)	Energy, from gas, natural		0.089	MJ surplus / MJ
Raw	(unspecified)	Energy, from coal, brown		0.061	MJ surplus / MJ
Raw	(unspecified)	Energy, from coal		0.0696	MJ surplus / MJ
Raw	(unspecified)	Gas, petroleum, 35 MJ per m3, in ground		3.115	MJ surplus / m3
Raw	(unspecified)	Gas, off-gas, oil production, in ground, 35MJ/m3	008006-14-2	3.115	MJ surplus / m3
Raw	(unspecified)	Gas, off-gas, 35.0 MJ per m3, oil production, in ground		3.115	MJ surplus / m3
Raw	(unspecified)	Gas, natural, in ground, 35MJ/m3	008006-14-2	3.063	MJ surplus / m3
Raw	(unspecified)	Gas, natural, feedstock, 35.0 MJ per m3, in ground		3.12	MJ surplus / m3
Raw	(unspecified)	Gas, natural, feedstock, 35 MJ per m3, in ground	008006-14-2	3.12	MJ surplus / m3
Raw	(unspecified)	Gas, natural, 42.0 MJ per m3, in ground		3.7	MJ surplus / m3
Raw	(unspecified)	Gas, natural, 39.0 MJ per m3, in ground		3.471	MJ surplus / m3
Raw	(unspecified)	Gas, natural, 38.8 MJ per m3, in ground		3.453	MJ surplus / m3
Raw	(unspecified)	Gas, natural, 36.6 MJ per m3, in ground	008006-14-2	3.26	MJ surplus / m3
Raw	(unspecified)	Gas, natural, 35.9 MJ per m3, in ground	008006-14-2	3.133	MJ surplus / m3
Raw	(unspecified)	Gas, natural, 35.2 MJ per m3, in ground		3.133	MJ surplus / m3
Raw	(unspecified)	Gas, natural, 35.0 MJ per m3, in ground		3.115	MJ surplus / m3
Raw	(unspecified)	Gas, natural, 35 MJ per m3, in ground	008006-14-2	3.115	MJ surplus / m3
Raw	(unspecified)	Gas, natural, 31.65 MJ per m3, in ground		2.817	MJ surplus / m3
Raw	(unspecified)	Gas, mine, off-gas, process, 39.8MJ/m3, coal mining/m3	008006-14-2	3.196	MJ surplus / m3
Raw	(unspecified)	Oil, crude, 38400 MJ per m3, in ground		3190	MJ surplus / l
Raw	(unspecified)	Oil, from technosphere, 38MJ/kg		3.59	MJ surplus / kg
Raw	(unspecified)	Oil, crude, in ground, 45MJ/kg		3.59	MJ surplus / kg
Raw	(unspecified)	Oil, crude, feedstock, 42 MJ per kg, in ground		3.486	MJ surplus / kg
Raw	(unspecified)	Oil, crude, feedstock, 41 MJ per kg, in ground		3.403	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 45.0 MJ per kg, in ground		3.735	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 44.6 MJ per kg, in ground		3.702	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 44.0 MJ per kg, in ground		3.652	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 43.4 MJ per kg, in ground		3.598	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 42.8 MJ per kg, in ground		3.54	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 42.7 MJ per kg, in ground		3.54	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 42.6 MJ per kg, in ground		3.536	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 42.0 MJ per kg, in ground		3.486	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 41.9 MJ per kg, in ground		3.478	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 41.0 MJ per kg, in ground		3.403	MJ surplus / kg
Raw	(unspecified)	Oil, crude, 41 MJ per kg, in ground		3.4	MJ surplus / kg
Raw	(unspecified)	Gas, natural, feedstock, 46.8 MJ per kg, in ground	008006-14-2	4.17	MJ surplus / kg
Raw	(unspecified)	Gas, natural, 51.3 MJ per kg, in ground	008006-14-2	2.697	MJ surplus / kg
Raw	(unspecified)	Gas, natural, 50.3 MJ per kg, in ground		2.697	MJ surplus / kg
Raw	(unspecified)	Gas, natural, 46.8 MJ per kg, in ground	008006-14-2	4.17	MJ surplus / kg
Raw	(unspecified)	Gas, natural, 30.3 MJ per kg, in ground	008006-14-2	2.69	MJ surplus / kg
Raw	(unspecified)	Gas, mine, off-gas, process, 49.8 MJ/kg, coal mining/kg	008006-14-2	3.9	MJ surplus / kg
Raw	(unspecified)	Coal, hard, unspecified, in ground, 24MJ/kg		1.32	MJ surplus / kg
Raw	(unspecified)	Coal, feedstock, 26.4 MJ per kg, in ground		1.83	MJ surplus / kg
Raw	(unspecified)	Coal, brown, in ground, 12MJ/kg		0.5385	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 9.9 MJ per kg, in ground		0.604	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 8.2 MJ per kg, in ground		0.5	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 8.1 MJ per kg, in ground		0.494	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 8.0 MJ per kg, in ground		0.488	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 8 MJ per kg, in ground		0.458	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 7.9 MJ per kg, in ground		0.482	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 15.0 MJ per kg, in ground		0.915	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 15 MJ per kg, in ground		1.2	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 14.4 MJ per kg, in ground		0.9	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 14.1 MJ per kg, in ground		0.86	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 10.0 MJ per kg, in ground		0.61	MJ surplus / kg
Raw	(unspecified)	Coal, brown, 10 MJ per kg, in ground		0.61	MJ surplus / kg
Raw	(unspecified)	Coal, 30.6 MJ per kg, in ground		2.126	MJ surplus / kg
Raw	(unspecified)	Coal, 30.3 MJ per kg, in ground		2.105	MJ surplus / kg
Raw	(unspecified)	Coal, 29.3 MJ per kg, in ground		2.035	MJ surplus / kg
Raw	(unspecified)	Coal, 29.0 MJ per kg, in ground		2.014	MJ surplus / kg
Raw	(unspecified)	Coal, 28.6 MJ per kg, in ground		1.987	MJ surplus / kg
Raw	(unspecified)	Coal, 28.0 MJ per kg, in ground		1.945	MJ surplus / kg
Raw	(unspecified)	Coal, 27.1 MJ per kg, in ground		1.882	MJ surplus / kg
Raw	(unspecified)	Coal, 26.4 MJ per kg, in ground		1.834	MJ surplus / kg
Raw	(unspecified)	Coal, 24.1 MJ per kg, in ground		1.674	MJ surplus / kg
Raw	(unspecified)	Coal, 24.0 MJ per kg, in ground		1.67	MJ surplus / kg
Raw	(unspecified)	Coal, 23.0 MJ per kg, in ground		1.598	MJ surplus / kg
Raw	(unspecified)	Coal, 22.8 MJ per kg, in ground		1.57	MJ surplus / kg
Raw	(unspecified)	Coal, 22.6 MJ per kg, in ground		1.57	MJ surplus / kg
Raw	(unspecified)	Coal, 22.4 MJ per kg, in ground		1.556	MJ surplus / kg
Raw	(unspecified)	Coal, 22.1 MJ per kg, in ground		1.535	MJ surplus / kg
Raw	(unspecified)	Coal, 21.5 MJ per kg, in ground		1.493	MJ surplus / kg
Raw	(unspecified)	Coal, 20.5 MJ per kg, in ground		1.423	MJ surplus / kg
Raw	(unspecified)	Coal, 20.0 MJ per kg, in ground		1.389	MJ surplus / kg
Raw	(unspecified)	Coal, 19.5 MJ per kg, in ground		1.355	MJ surplus / kg
Raw	(unspecified)	Coal, 18.5 MJ per kg, in ground		1.284	MJ surplus / kg
Raw	(unspecified)	Coal, 18.0 MJ per kg, in ground		1.25	MJ surplus / kg
Raw	(unspecified)	Coal, 18 MJ per kg, in ground		1.25	MJ surplus / kg
Raw	(unspecified)	Coal, 13.3 MJ per kg, in ground		0.923	MJ surplus / kg
Minerals	**MJ Surplus**				
Raw	(unspecified)	Zinc, in ground	007440-66-6	4.09	MJ Surplus / kg
Raw	(unspecified)	Zinc ore, in ground		0.164	MJ Surplus / kg
Raw	(unspecified)	Zinc 9%, Lead 5%, in sulfide, in ground		4.09	MJ Surplus / kg
Raw	(unspecified)	Zinc 9%, in sulfide, Zn 5.34% and Pb 2.97% in crude ore, in ground		4.09	MJ Surplus / kg
Raw	(unspecified)	Tungsten ore, in ground		0.927	MJ Surplus / kg
Raw	(unspecified)	Tin, in ground	007440-31-5	600	MJ Surplus / kg
Raw	(unspecified)	Tin, 79% in cassiterite, 0.1% in crude ore, in ground	007440-31-5	600	MJ Surplus / kg
Raw	(unspecified)	Tin ore, in ground		0.06	MJ Surplus / kg
Raw	(unspecified)	Pyrolusite, in ground	014854-26-3	0.313	MJ Surplus / kg
Raw	(unspecified)	Nickel, in ground	007440-02-0	23.75	MJ Surplus / kg
Raw	(unspecified)	Nickel, 1.98% in silicates, 1.04% in crude ore, in ground	007440-02-0	23.75	MJ Surplus / kg
Raw	(unspecified)	Nickel, 1.13% in sulfides, 0.76% in crude ore, in ground	007440-02-0	23.75	MJ Surplus / kg
Raw	(unspecified)	Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground	007440-02-0	23.75	MJ Surplus / kg
Raw	(unspecified)	Nickel ore, in ground		0.356	MJ Surplus / kg
Raw	(unspecified)	Ni, Ni 3.7E-2%, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Cu 5.2E-2% in ore, in ground		23.75	MJ Surplus / kg
Raw	(unspecified)	Ni, Ni 2.3E+0%, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Cu 3.2E+0% in ore, in ground		23.75	MJ Surplus / kg
Raw	(unspecified)	Molybdenum, in ground	007439-98-7	41	MJ Surplus / kg
Raw	(unspecified)	Molybdenum, 0.11% in sulfide, Mo 0.41% and Cu 0.36% in crude ore, in ground	007439-98-7	41	MJ Surplus / kg
Raw	(unspecified)	Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore, in ground	007439-98-7	41	MJ Surplus / kg
Raw	(unspecified)	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore, in ground	007439-98-7	41	MJ Surplus / kg
Raw	(unspecified)	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.22% in crude ore, in ground	007439-98-7	41	MJ Surplus / kg
Raw	(unspecified)	Molybdenum, 0.016% in sulfide, Mo 8.2E-3% and Cu 0.27% in crude ore, in ground	007439-98-7	41	MJ Surplus / kg
Raw	(unspecified)	Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore, in ground	007439-98-7	41	MJ Surplus / kg
Raw	(unspecified)	Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore, in ground	007439-98-7	41	MJ Surplus / kg
Raw	(unspecified)	Molybdenum ore, in ground		0.041	MJ Surplus / kg
Raw	(unspecified)	Mercury, in ground	007439-97-6	165.5	MJ Surplus / kg
Raw	(unspecified)	Manganese, in ground	007439-96-5	0.313	MJ Surplus / kg
Raw	(unspecified)	Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground	007439-96-5	0.313	MJ Surplus / kg
Raw	(unspecified)	Manganese ore, in ground		0.141	MJ Surplus / kg
Raw	(unspecified)	Lead, in ground	007439-92-1	7.35	MJ Surplus / kg
Raw	(unspecified)	Lead, 5%, in sulfide, Pb 2.97% and Zn 5.34% in crude ore, in ground		7.35	MJ Surplus / kg
Raw	(unspecified)	Lead ore, in ground		0.368	MJ Surplus / kg
Raw	(unspecified)	Iron, in ground	007439-89-6	0.051	MJ Surplus / kg
Raw	(unspecified)	Iron, 46% in ore, 25% in crude ore, in ground	007439-89-6	0.051	MJ Surplus / kg
Raw	(unspecified)	Iron ore, in ground		0.029	MJ Surplus / kg
Raw	(unspecified)	Cu, Cu 5.2E-2%, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Ni 3.7E-2% in ore, in ground		36.7	MJ Surplus / kg
Raw	(unspecified)	Cu, Cu 3.2E+0%, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0% in ore, in ground		36.7	MJ Surplus / kg
Raw	(unspecified)	Copper, in ground	007440-50-8	36.7	MJ Surplus / kg
Raw	(unspecified)	Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore, in ground	007440-50-8	36.7	MJ Surplus / kg
Raw	(unspecified)	Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore, in ground	007440-50-8	36.7	MJ Surplus / kg
Raw	(unspecified)	Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore, in ground	007440-50-8	36.7	MJ Surplus / kg
Raw	(unspecified)	Copper, 1.13% in sulfide, Cu 0.76% and Ni 0.76% in crude ore, in ground		36.7	MJ Surplus / kg
Raw	(unspecified)	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground	007440-50-8	36.7	MJ Surplus / kg
Raw	(unspecified)	Copper, 0.97% in sulfide, Cu 0.36% and Mo 4.1E-2% in crude ore, in ground	007440-50-8	36.7	MJ Surplus / kg
Raw	(unspecified)	Copper, 0.59% in sulfide, Cu 0.22% and Mo 8.2E-3% in crude ore, in ground	007440-50-8	36.7	MJ Surplus / kg
Raw	(unspecified)	Copper, 0.52% in sulfide, Cu 0.27% and Mo 8.2E-3% in crude ore, in ground	007440-50-8	36.7	MJ Surplus / kg
Raw	(unspecified)	Copper ore, in ground		0.415	MJ Surplus / kg
Raw	(unspecified)	Cinnabar, in ground		165.5	MJ Surplus / kg
Raw	(unspecified)	Chromium, in ground	007440-47-3	0.9165	MJ Surplus / kg
Raw	(unspecified)	Chromium, 25.5% in chromite, 11.6% in crude ore, in ground	007440-47-3	0.9165	MJ Surplus / kg
Raw	(unspecified)	Chromium ore, in ground		0.275	MJ Surplus / kg
Raw	(unspecified)	Chromium compounds		0.9165	MJ Surplus / kg
Raw	(unspecified)	Bauxite, in ground	001318-16-7	0.5	MJ Surplus / kg
Raw	(unspecified)	Aluminium, in ground	001318-16-7	2.38	MJ Surplus / kg
Raw	(unspecified)	Aluminium, 24% in bauxite, 11% in crude ore, in ground	001318-16-7	2.38	MJ Surplus / kg

Normalisation weighting factors as follows (per capita used in this study).

Normalization-Weighting set Australian annual per capita	
Normalization	
Global Warming	0.00003832
Photochemical oxidation	0.01395
Eutrophication	0.0705
Carcinogens	3443
Land use	0.042
Water Use	0.0002305
Solid waste	0.00072
Fossil fuels	0.00002418
Minerals	0.0003834

Appendix D Impact of capital equipment within laundry

An estimate of capital equipment impacts within the laundry facility was developed using input output data and actual depreciation charges incurred by a modern laundry facility.

Depreciation charges were used because they reflect amortisation of capital expenditure required to purchase equipment and buildings, and because such amortisation is undertaken over the universally accepted lifetimes of such items.

This annual amortisation figure is then matched to the annual productive output (measured in kg's of laundry processed), to give an amortisation amount per kg of production.

The dollar amount of depreciation per kg of laundry processed is then converted to an environmental impact using the Dutch Input-Output database for non-European OECD countries (1995).

Table 11-1 describes the impacts of laundry capital over the entire life cycle of a reusable gown.

Table 11-1 Calculation of capital impacts of laundry.

Description	Amount	Unit
Annual depreciation of buildings and equipment	420,000	$
Annual laundry output	4,700,000	kg
Total depreciation per kg	0.089	$

Capital impacts (Machine and electrcial equipment industry sector) per gown processed (from Dutch IO Database 1995, non-European OECD countries)	Unit	Per gown and huck towel (0.36 kg)	Total reusable pack impact (life cycle)	% contribution of capital
Global Warming	kg CO2	1.28E-02	5.06E-01	3%
Photochemical oxidation	kg C2H4	1.79E-05	1.58E-04	11%
Eutrophication	kg PO4--- eq	5.13E-06	4.62E-04	1%
Carcinogens	DALY	4.03E-11	7.55E-09	1%
Land use	Ha a	1.98E-07	1.73E-06	11%
Water Use	KL H2O	5.07E-04	1.12E-02	5%
Solid waste	kg	NA		
Fossil fuels	MJ surplus	NA		
Minerals	MJ Surplus	NA		

NA = data not available from IO database

Appendix E Nutrient balance

Phosphate and nitrate emissions due to gown soiling and detergent use during washing are potentially important contributors to the total eutrophication impacts of the reusable gown considered in this study. Determination of the of these emissions provided a challenge for this study, as directly measured emission data was not available.

As an alternative to direct measurement, a nutrient balance approach was taken that determined the total nutrients in both garment soiling and detergents used in washing, then accounted for the final emission of these nutrients to the environment, with only those emissions to water being considered significant contributors to eutrophication.

Emissions from the laundry sewerage flow were assumed to be treated by Melbourne's Eastern Treatment Plant, whereby a proportion of nutrients were assumed to removed prior to emission of the final waste stream to ocean.

In order to undertake the nutrient balance, nutrient inputs were estimated for soiling and detergents as follows.

Estimation of gown soiling

Gown soiling varies considerably depending on the surgical procedure performed. Anecdotal evidence suggests most soiling to be minor in nature, however no objective data regarding this was available. Instead, an estimate of soiling was developed using two alternative methodologies, and nutrient loads estimated to be the highest of these methods.

<u>Blood Method – Each gown and towel pack soiled with 0.5 litres blood</u>

The first method calculated the phosphorous and nitrogen levels present in 0.5litres of blood and assumed that this level of soiling occurred to every gown. Total phosphorous and nitrogen levels were estimated using typical concentrations as described by Walmsley and White (Walmsley and White 1994).

Table Appx. E-1 Gown soiling - Blood Method

Blood soiling of gown	0.5	litres
Blood plasma	55%	of total volume
Nitrogen and Phosphorus levels per unit of Plasma (from Walmsley et. al. (1994))		
Typical urea ((NH2)2CO)	7	mmol/litre plasma
Total N	14	mmol/litre plasma
Total N (mass)	196	mg/litre plasma
Typical phosphate (PO4)	0.9	mmol/litre plasma
Total P	0.9	mmol/litre plasma
Total P (mass)	28.7	mg/litre plasma
Nitrogen and Phosphorus levels per unit of blood (assume plasma 55% of total blood volume)		
Total N (mass)	107.8	mg/litre blood
Total P (mass)	15.8	mg/litre blood
Nitrogen and Phosphorus levels per gown and towel pack (assume 0.5 litres of blood per pack)		
Total N (mass)	53.9	mg/pack
Total P (mass)	7.9	mg/pack
Nitrogen and Phosphorus levels per kg dry linen. Mass of pack(kg):	0.361	
Total N (mass)	149.4	mg/kg dry linen
Total P (mass)	21.9	mg/kg dry linen

Table Appx. E-1 describes the calculation of the nutrient content per kilogram of dry linen processed by the laundry (149.4mg nitrogen, 21.9mg phosphorous per dry kg laundered).

Abattoir Method – Each gown and towel pack soiled with 0.5 litres untreated wastewater from a meat processing plant

The second method calculated the phosphorous and nitrogen levels present in 0.5 litres of meat processing plant effluent, which is assumed to soil the gown and huck towel. Total phosphorous and nitrogen levels were estimated using typical concentrations for a meat processing plant as identified by as described by the UNSW – CRC for Waste Management & Pollution Control (UNSW - CRC for Waste Management and Pollution Control. 1998).

Table Appx. E-2 Gown soiling – Abattoir Method

Nitrogen and Phosphorus levels per unit of meat processing plant wastewater		
Total N (mass)	148	mg/litre wastewater from UNSW(1998)
Total P (mass)	30.0	mg/litre wastewater from UNSW(1998)
Nitrogen and Phosphorus levels per gown and towel pack (assume 0.5 litres of wastewater per pack)		
Total N (mass)	74	mg/pack
Total P (mass)	15.0	mg/pack
Nitrogen and Phosphorus levels per kg dry linen. Mass of pack(kg):	0.361	
Total N (mass)	205.1	mg/kg dry linen
Total P (mass)	41.6	mg/kg dry linen

Table Appx. E-2 describes the calculation of the nutrient content per kilogram of dry linen processed by the laundry under the 'Abattoir method' (205.1mg nitrogen, 41.6 mg phosphorous per dry kg laundered).

Of the two methods the 'Abattoir Method' was shown to deliver a higher nutrient load, so was used in final calculations.

Estimation of detergent nutrient levels (Low P detergent – base case)

Although 'low phosphate' detergents were used during the wash process, they do contain a proportion of phosphorus based compounds as described in the detergent breakdown described by Table Appx. E-3.

Table Appx. E-3 Breakdown of detergent chemistry used in this study.

	% by mass	mls/kg dry linen (mls)	Specific gravity	mass/kg dry linen (g)	LCA data source
Detergent					
Fluorescent whitener	0.1%	0.009	1	0.009	Ecoinvent
Nonionic surfactant	20.0%	1.8	1	1.8	Ecoinvent
Anionic surfactant	6.0%	0.54	1	0.54	Ecoinvent
Other	73.9%	6.651	1	6.651	
Total	100.0%	9	1	9	
memo: Total P	*0.8%*			*0.072*	%P provided by Ecolab
Builder					
Sodium hydroxide	20.0%	1.2	1.6	1.92	Ecoinvent
Alkaline salts&silicates	3.0%	0.18	1.6	0.288	Ecoinvent
Other	77.0%	4.62	1.6	7.392	
Total	100.0%	6	1.6	9.6	
memo: Total P	*0.5%*			*0.048*	%P provided by Ecolab
Bleach					
Sodium hypochlorite	10.0%	0.1	1.1	0.11	Ecoinvent
Other	90.0%	0.9	1.1	0.99	
Total	100.0%	1	1.1	1.1	
Sour softener					
Cationic surfactant	8.0%	0.16	1	0.16	Ecoinvent
Organic acids	30.0%	0.6	1	0.6	Ecoinvent
Other	62.0%	1.24	1	1.24	
Total	100.0%	2	1	2	
Total		18		21.7	
memo:total P				*0.12*	Calculated from above

Table Appx. E-3 shows that an equivalent of 0.12g (120 milligrams) of phosphorous (P) is used in the wash process per dry kilogram of laundry processed.

Estimation of combined detergent and soiling nutrient emissions to the environment

As mentioned above, a nutrient balance method was applied that assumes that all nutrients flowing into the laundry (in soiling and detergents) ultimately flow to the environment. It is assumed that only those nutrients that are not retained by the municipal wastewater treatment plant ultimately flow to water and contribute to eutrophication.

A key determination of final eutrophication impacts is the effectiveness of the municipal waste water treatment plant in retaining nutrients. A prior study undertaken by Saouter (2002) estimated emissions associated with detergent use by using sewerage treatment plant retention rates for nutrients considered. A similar method has been applied in this study using retention rates for the Eastern Treatment Plant, near Melbourne. Table Appx. E-4 describes these retention rates.

Table Appx. E-4 Eatern Treatment Plant Retention Rates.

	Sewerage treatment plant effectiveness Data from Melbourne Water (2005)		
	Eastern Treatment Plant raw sewage	Eastern Treatment Plant outfall to ocean	**% retention of nutrients**
	g/kL	g/kL	**%**
Total N	74	30	**59%**
Total P	18.4	8.4	**54%**

Using the above retention rates in combination with nutrient loads associated with soiling and detergent use, it was possible to complete a nutrient balance for the system and hence estimate final nutrient flows to the environment.

Figure Appx. E-1 Nutrient balance for processing 1 kg soiled, dry fabric.

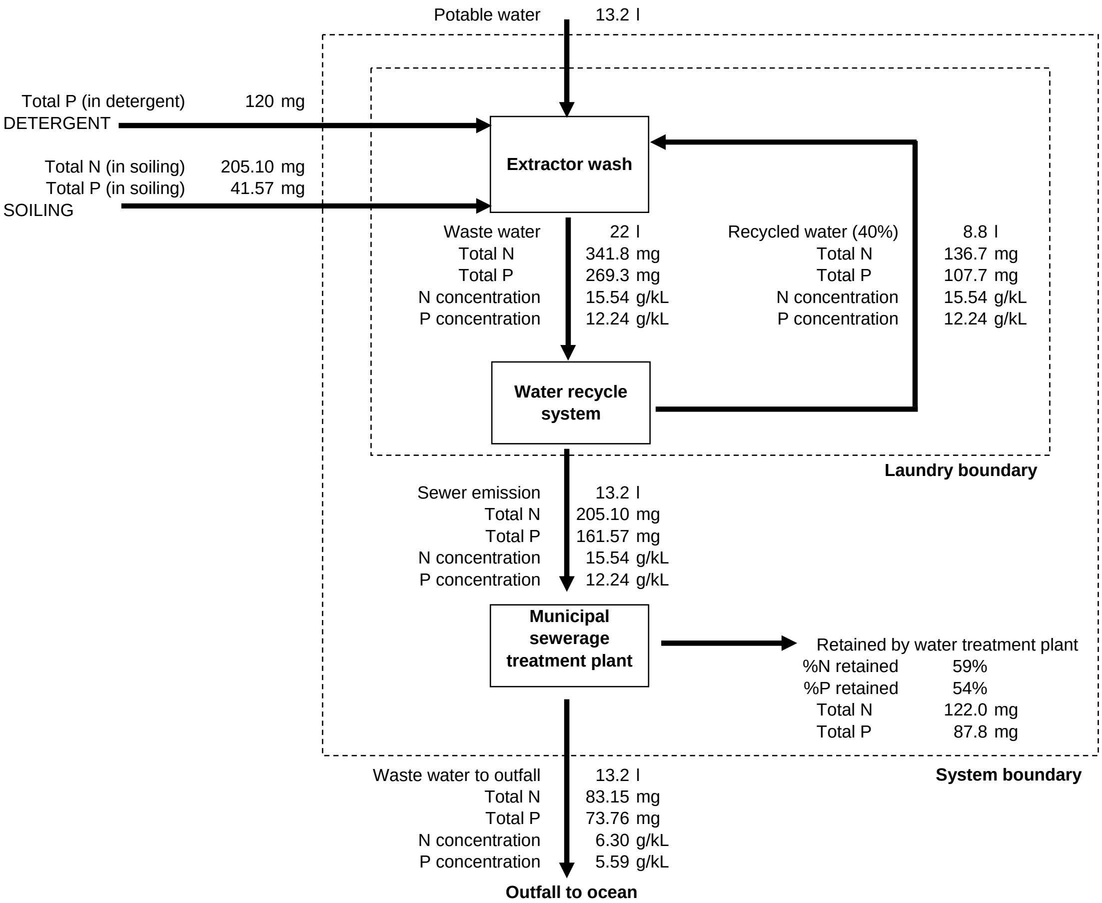


Figure Appx. E-1 describes the nutrient balance used in the study. The balance concludes that emissions to ocean are the equivalent of 6.3grams per kilolitre total nitrogen and 5.59 grams per kilolitre total phosphorous.

Estimation of detergent nutrient levels (high P detergent – sensitivity)
In addition to considering low P detergents, a high P detergent was considered as a sensitivity study. This detergent type might be more typical of an older laundry facility that is less focussed on environmental emissions to water.

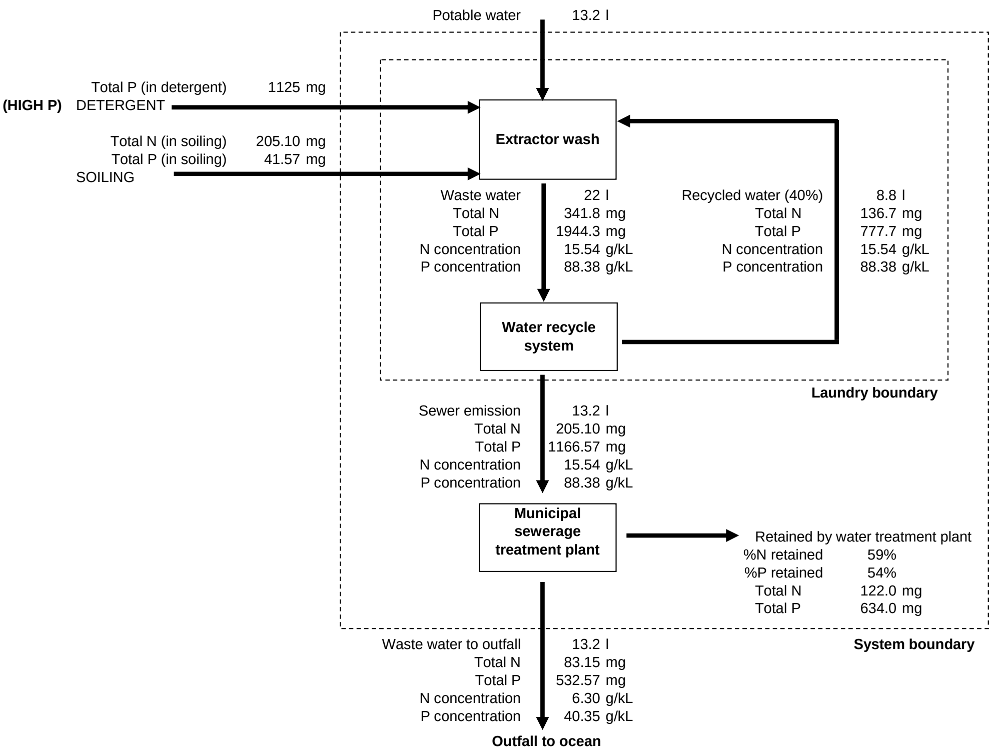
To simulate a high-P detergent, a typical chemistry was adopted that uses sodium tri-polyphosphate as the detergent builder, which is assumed to comprise 25% of the detergent dose {Centre European Etudes des Polyphosphates, #9}. The dosage is assumed to be identical to the low P detergent discussed above, and a new total P proportion calculated, as shown in Table Appx. E-5.

Table Appx. E-5 High - P detergent chemistry used in this study.

	% by mass	mls/kg dry linen (mls)	Specific gravity	mass/kg dry linen (g)	LCA data source
SODIUM TRIPOLYPHOPHATE (STPP) $Na_5P_3O_{10}$ (total P = 1.12	25%	4.5	1	4.5	molar mass 368 (25%P)
OTHER	75%	13.5	1	13.5	
Total		18		18	
memo:total P				*1.125*	Calculated from above

The higher P concentration was then introduced into the nutrient balance described above, using identical wastewater treatment retention rates, and identical soiling rates. The resulting nutrient balance is shown in Figure Appx. E-2.

Figure Appx. E-2 Nutrient balance - High P.



The above balance concludes that emissions to ocean are the equivalent of 6.30 grams per kilolitre total nitrogen and 40.35 grams per kilolitre total phosphorous.

Appendix F Non classified substances.

Compartment	Substance	Unit	Disposable surgical gown and huck towel	Reusable surgical gown and huck towel
Raw	Additives	µg	-0.074229007	2.8074872
Raw	Air	pg	-28.952435	194.59315
Raw	Aluminum hydroxide	mg	0.20545	4.3523611
Raw	Anhydrite, in ground	µg	937.53823	67.322894
Raw	bagasse, 8.7MJ/kg	mg	-14.643545	11.281277
Raw	Barite, 15% in crude ore, in ground	mg	25.475154	14.182598
Raw	Baryte, in ground	pg	-0.013666615	0.091855128
Raw	Basalt, in ground	mg	5.685936	1.7485931
Raw	Borax, in ground	ng	90.503045	49.597077
Raw	Cadmium, 0.30% in sulfide, Cd 0.18%, Pb, Zn, Ag, In, i	µg	17.996558	2.4557291
Raw	Calcite, in ground	g	2.1487224	0.49486048
Raw	Calcium sulfate, in ground	pg	-0.000390714	0.002626039
Raw	Carbon	µg	1.5454211	2.5611011
Raw	Carbon dioxide, in air	g	1.08E+02	3.02E+00
Raw	Carbon, in organic matter, in soil	mg	0.011912534	29.158486
Raw	Cerium, 24% in bastnasite, 2.4% in crude ore, in groun	pg	-1.30E-08	-3.91E-07
Raw	Chrysotile, in ground	µg	23.685971	75.645271
Raw	Clay, bentonite, in ground	mg	21.299411	8.0525443
Raw	Clay, unspecified, in ground	mg	762.08028	308.18876
Raw	Cobalt, in ground	µg	0.053903647	8.9698489
Raw	Colemanite, in ground	µg	48.64212	70.572213
Raw	Diatomite, in ground	µg	0.004094706	33.095052
Raw	Dolomite, in ground	mg	2.1745784	10.792968
Raw	Energy, from biomass	kJ	71.561797	68.42415
Raw	Energy, from hydro power	kJ	-1.1392389	21.067371
Raw	Energy, from hydrogen	J	-7.19E-08	4.83E-07
Raw	Energy, from peat	J	-1.78E-10	1.20E-09
Raw	Energy, from solar	J	-0.41031064	2.7577521
Raw	Energy, from sulfur	J	-1.27E-08	8.56E-08
Raw	Energy, from uranium	J	-4.93E-07	3.31E-06
Raw	Energy, from wood	kJ	-9.52E-14	4.7231908
Raw	Energy, gross calorific value, in biomass	Wh	344.74521	12.205195
Raw	Energy, gross calorific value, in biomass, primary fores	kJ	0.000825872	2.0214982
Raw	Energy, kinetic (in wind), converted	kJ	2.57E+00	1.03E+00
Raw	Energy, kinetic, flow, in wind	J	-15.200435	700.51674
Raw	Energy, potential (in hydropower reservoir), converted	kJ	113.22145	19.059981
Raw	Energy, recovered	J	1.27E-07	-8.52E-07
Raw	Energy, solar, converted	J	27.905199	15.290289
Raw	Energy, unspecified	J	-8.86E-09	5.96E-08
Raw	Feldspar, in ground	ng	-5.7969862	355.74443
Raw	Ferromanganese	µg	-3.4078637	470.28089
Raw	Fish	mg	x	1.1037243
Raw	Fluorine, 4.5% in apatite, 1% in crude ore, in ground	µg	384.01335	45.155093
Raw	Fluorine, 4.5% in apatite, 3% in crude ore, in ground	mg	0.19516103	7.0808308
Raw	Fluorine, in ground	µg	23.619706	615.47539
Raw	Fluorspar, 92%, in ground	mg	11.36881	6.3945029
Raw	Fluorspar, in ground	pg	-0.000270388	0.001817312
Raw	Gadolinium, 0.15% in bastnasite, 0.015% in crude ore,	pg	-1.27E-10	-6.46E-14
Raw	Gallium, 0.014% in bauxite, in ground	pg	79.20085	41.411742
Raw	Gold, Au 1.1E-4%, Ag 4.2E-3%, in ore, in ground	ng	23.184469	30.350829
Raw	Gold, Au 1.3E-4%, Ag 4.6E-5%, in ore, in ground	ng	42.512147	55.652797
Raw	Gold, Au 1.4E-4%, in ore, in ground	ng	50.903146	66.637476
Raw	Gold, Au 2.1E-4%, Ag 2.1E-4%, in ore, in ground	ng	7.77E+01	1.02E+02
Raw	Gold, Au 4.3E-4%, in ore, in ground	ng	19.269398	25.225613
Raw	Gold, Au 4.9E-5%, in ore, in ground	ng	46.152668	60.418619
Raw	Gold, Au 6.7E-4%, in ore, in ground	ng	71.451828	93.537737
Raw	Gold, Au 7.1E-4%, in ore, in ground	ng	80.569339	105.47351
Raw	Gold, Au 9.7E-4%, Ag 9.7E-4%, Zn 0.63%, Cu 0.38%,	ng	4.8278146	6.3201062
Raw	Granite, in ground	pg	29.068985	22.533015
Raw	Graphite, from technosphere, 50MJ/kg	µg	3.86E-01	9.84E+01
Raw	Gravel, in ground	g	34.063104	2.464719
Raw	Gypsum, in ground	mg	0.95671473	2.9375329
Raw	Helium, 0.08% in natural gas, in ground	pg	399.8805	209.22554
Raw	Indium, 0.005% in sulfide, In 0.003%, Pb, Zn, Ag, Cd, i	ng	303.7138	42.901898
Raw	Kaolinite, 24% in crude ore, in ground	mg	571.08175	0.065245362
Raw	Kieserite, 25% in crude ore, in ground	mg	96.223444	4.50E-04
Raw	Landfill cover, m3	cm3	399.6	0.13500045
Raw	Lanthanum, 7.2% in bastnasite, 0.72% in crude ore, in	pg	1.81E-08	3.58E-08
Raw	Lead, 5.0% in sulfide, Pb 3.0%, Zn, Ag, Cd, In, in grou	µg	913.57165	518.52612
Raw	Limestone, in ground	g	11.250923	0.77806089
Raw	Magnesite, 60% in crude ore, in ground	mg	9.1632205	4.3244951
Raw	Magnesium, 0.13% in water	µg	4.3149561	0.19868724
Raw	Metamorphous rock, graphite containing, in ground	µg	32.598626	16.975104
Raw	Molybdenum, 0.11% in sulfide, Mo 4.1E-2% and Cu 0.	mg	1.1665823	0.46549874
Raw	Neodymium, 4% in bastnasite, 0.4% in crude ore, in gr	pg	-6.19E-09	-1.10E-07
Raw	Nitrogen, in air	pg	-2.8872455	19.405559
Raw	Occupation, arable	cm2a	x	73.300899
Raw	Occupation, arable, non-irrigated, diverse-intensive	cm2a	x	10.402357
Raw	Occupation, dump site	mm2a	50.149828	122.60187
Raw	Occupation, forest	mm2a	x	188.92763
Raw	Occupation, forest, intensive	m2a	0.2116586	5.20E-06
Raw	Occupation, forest, intensive, normal	cm2a	215.43728	7.4088616
Raw	Occupation, forest, intensive, short-cycle	cm2a	0.002071699	49.865557
Raw	Occupation, industrial area	mm2a	25.465202	36.343471
Raw	Occupation, mineral extraction site	m2s	852.20732	709.81937
Raw	Occupation, traffic area	mm2a	257.20731	20.987779
Raw	Occupation, urban, continuously built	mm2a	x	9.45E+02
Raw	Occupation, urban, discontinuously built	m2s	17.081343	270.24861
Raw	Occupation, urban, green areas	mm2a	-9.6473196	321.23257
Raw	Occupation, water bodies, artificial	mm2a	87.925801	78.638689
Raw	Occupation, water courses, artificial	cm2a	-0.68706389	17.084001
Raw	Oil, crude, 42 MJ per kg, in ground	g	10.793601	5.8285499
Raw	Olivine, in ground	µg	380.50558	25.86048
Raw	Oxygen, in air	mg	-2.17E-02	5.75E+01
Raw	Paper waste, feedstock	g	x	1.65E+00
Raw	Pd, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%	ng	8.9037884	7.5436216
Raw	Pd, Pd 7.3E-4%, Pt 2.5E-4%, Rh 2.0E-5%, Ni 2.3E+0%	ng	21.398406	18.129524
Raw	Peat, in ground, 13MJ/kg	mg	461.07272	20.200892
Raw	Phosphorus pentoxide	mg	0.094478826	2.4619016
Raw	Phosphorus, 18% in apatite, 12% in crude ore, in grou	mg	0.78794549	34.49829
Raw	Phosphorus, 18% in apatite, 4% in crude ore, in groun	mg	1.5360534	0.18062035
Raw	Potassium chloride	pg	-0.87132614	5.8562983
Raw	Praseodymium, 0.42% in bastnasite, 0.042% in crude	pg	6.54E-12	3.81E-11
Raw	Pt, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0%	pg	404.86884	159.02694
Raw	Pt, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Ni 3.7E-2%,	ng	1.4513953	0.57008828
Raw	Refractories, from technosphere	µg	-1.3755213	251.48514
Raw	Rh, Rh 2.0E-5%, Pt 2.5E-4%, Pd 7.3E-4%, Ni 2.3E+0%	pg	126.77496	49.641367
Raw	Rh, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%	pg	397.07541	155.4831
Raw	Rhenium, in crude ore, in ground	pg	214.75948	46.613059
Raw	Rutile, in ground	pg	-3.69E-18	2.48E-17
Raw	Samarium, 0.3% in bastnasite, 0.03% in crude ore, in g	pg	-1.55E-10	-1.46E-12
Raw	Sand, river, in ground	mg	-2.7911179	184.22002
Raw	Sand, unspecified, in ground	mg	23.349523	1.8120663
Raw	Secondary glass	µg	-2.7025579	102.21649
Raw	Shale, in ground	mg	2.6542494	0.19059492
Raw	Silver, 0.007% in sulfide, Ag 0.004%, Pb, Zn, Cd, In, in	ng	520.05041	673.99153
Raw	Silver, 3.2ppm in sulfide, Ag 1.2ppm, Cu and Te, in cru	ng	371.05665	480.81628
Raw	Silver, Ag 2.1E-4%, Au 2.1E-4%, in ore, in ground	ng	34.251445	44.388949
Raw	Silver, Ag 4.2E-3%, Au 1.1E-4%, in ore, in ground	ng	78.226212	101.3791
Raw	Silver, Ag 4.6E-5%, Au 1.3E-4%, in ore, in ground	ng	76.678675	99.373408
Raw	Silver, Ag 9.7E-4%, Au 9.7E-4%, Zn 0.63%, Cu 0.38%	ng	50.59358	65.567944
Raw	Sodium chloride, in ground	g	1.2942846	2.7270149
Raw	Sodium nitrate, in ground	ng	417.56162	22.525686
Raw	Sodium sulphate, various forms, in ground	mg	6.5626809	0.22341847
Raw	Stibnite, in ground	µg	0.000425528	3.4392897
Raw	Sulfur dioxide, secondary	mg	0.27997568	74.265398
Raw	Sulfur, bonded	pg	-0.68705646	4.6177974
Raw	Sulfur, in ground	mg	8.2733024	0.57884962
Raw	Sylvite, 25 % in sylvinite, in ground	mg	3.4692803	193.65801
Raw	Talc, in ground	mg	53.463771	0.006307656
Raw	Tantalum, 81.9% in tantalite, 1.6E-4% in crude ore, in g	ng	409.22282	5.31E+02
Raw	Tellurium, 0.5ppm in sulfide, Te 0.2ppm, Cu and Ag, in	ng	55.659424	7.21E+01
Raw	TiO2, 54% in ilmenite, 2.6% in crude ore, in ground	mg	7.3117222	0.76704786
Raw	TiO2, 95% in rutile, 0.40% in crude ore, in ground	µg	751.20716	40.956662
Raw	Transformation, from arable	cm2	0.000224735	73.301074
Raw	Transformation, from arable, non-irrigated	mm2	468.14236	1.1409416
Raw	Transformation, from arable, non-irrigated, fallow	mm2	0.002959521	0.001439347
Raw	Transformation, from dump site, inert material landfill	mm2	0.10827811	0.042522388
Raw	Transformation, from dump site, residual material landf	mm2	0.31601289	0.12266048
Raw	Transformation, from dump site, sanitary landfill	mm2	0.03101019	0.005226047
Raw	Transformation, from dump site, slag compartment	mm2	0.007551018	0.000562261
Raw	Transformation, from forest	mm2	5.7477686	1.8282649
Raw	Transformation, from forest, extensive	cm2	15.95226	0.22610389
Raw	Transformation, from forest, intensive, clear-cutting	mm2	0.007398957	18.110538
Raw	Transformation, from forest, intensive, short-cycle	mm2	x	102.38772
Raw	Transformation, from industrial area	mm2	0.068188157	0.022382132
Raw	Transformation, from industrial area, benthos	mm2	0.000265429	5.46E-05
Raw	Transformation, from industrial area, built up	mm2	0.000548219	6.42E-05
Raw	Transformation, from industrial area, vegetation	mm2	0.000935196	0.000109594
Raw	Transformation, from mineral extraction site	mm2	0.98221643	0.3644141
Raw	Transformation, from pasture and meadow	mm2	0.93511161	0.54583274
Raw	Transformation, from pasture and meadow, intensive	mm2	0.38204905	0.000930369
Raw	Transformation, from sea and ocean	mm2	2.9708613	0.80196868
Raw	Transformation, from shrub land, sclerophyllous	mm2	0.58835329	0.20996777
Raw	Transformation, from tropical rain forest	mm2	0.007398957	18.110538

Compartment	Substance	Unit	Disposable surgical gown and huck towel	Reusable surgical gown and huck towel
Air	1,4-Butanediol	pg	135.38935	176.58807
Air	Acenaphthene	pg	37.483009	175.11024
Air	Acetonitrile	µg	0.008044146	19.689776
Air	Acrolein	µg	6.6686769	0.41654822
Air	Acrylic acid	ng	6.5193895	8.5344722
Air	Actinides, radioactive, unspecified	µBq	4.6871372	623.60842
Air	Aerosols, radioactive, unspecified	µBq	110.99556	64.352967
Air	Aldehydes, unspecified	mg	1.2802011	0.062761161
Air	Aluminum	µg	756.04019	854.30429
Air	Antimony	µg	3.3706189	0.90916422
Air	Antimony-124	nBq	0.72923719	0.30611785
Air	Antimony-125	nBq	7.6102028	3.1945968
Air	Argon-41	mBq	43.759164	21.360542
Air	Arsine	pg	0.07599211	0.099480594
Air	Barium	µg	2.8031138	13.522721
Air	Barium-140	nBq	495.03237	207.80377
Air	Benzal chloride	pg	0.000964923	0.32900754
Air	Benzene, pentachloro-	ng	2.3993935	0.27588893
Air	Beryllium	µg	2.6913535	0.71315734
Air	Biphenyl	ng	221.63886	119.82625
Air	Boron	µg	113.08728	668.59872
Air	Boron trifluoride	pg	0.000567144	0.000742443
Air	Bromine	µg	19.071423	60.205493
Air	Butene	µg	4.6299508	1.5323631
Air	Butyrolactone	pg	39.179264	51.101416
Air	Calcium	µg	467.46697	52.076707
Air	Caprolactam	ng	-0.029668275	1.37E+00
Air	Carbon-14	mBq	441.57627	174.84929
Air	Carbon dioxide, land transformation	mg	1.1490836	280.37856
Air	Carbon disulfide	µg	85.297288	99.601327
Air	Cerium-141	nBq	120.00705	50.376331
Air	Cesium-134	nBq	5.7475658	2.4127026
Air	Cesium-137	nBq	101.88566	42.769376
Air	Chlorinated fluorocarbons, soft	pg	-0.001029474	0.006919231
Air	Chlorine	mg	0.058443176	1.3942288
Air	Chlorosilane, trimethyl-	pg	117.11987	153.32061
Air	Chromium	µg	63.451613	37.867101
Air	Chromium-51	nBq	7.6900302	3.2281063
Air	Cobalt	µg	10.164935	2.3945013
Air	Cobalt-58	nBq	10.708685	4.4952721
Air	Cobalt-60	nBq	94.601267	39.711541
Air	Copper	µg	22.3276	26.975408
Air	Cyanide	µg	17.106832	39.466003
Air	Ethyl cellulose	ng	2.37E+01	3.10E+01
Air	Ethylene diamine	µg	3.7640526	6.52E-06
Air	Fluoride	µg	-49.353593	464.49791
Air	Fluorine	µg	4.2608063	0.84088921
Air	Fluosilicic acid	ng	610.52312	317.15068
Air	Furan	µg	0.015277379	37.394639
Air	furans	pg	x	4.7468067
Air	Heat, waste	Mj	5.9680805	0.66309509
Air	Helium	µg	14.014962	3.6194175
Air	Hydrocarbons, aliphatic, alkanes, cyclic	µg	0.049102669	23.076938
Air	Hydrocarbons, aliphatic, alkanes, unspecified	µg	316.50101	680.38084
Air	Hydrocarbons, aliphatic, unsaturated	µg	261.24292	54.449783
Air	Hydrocarbons, aromatic	mg	24.287614	1.3976389
Air	Hydrocarbons, chlorinated	µg	1.3066994	0.58035335
Air	Hydrocarbons, unspecified	mg	5.2428554	3.2127726
Air	Hydrogen	mg	43.040113	4.2373915
Air	Hydrogen-3, Tritium	Bq	2.5585968	1.2890723
Air	Hydrogen chloride	mg	47.128609	61.890578
Air	Hydrogen cyanide	pg	-1.26E-23	8.49E-23
Air	Hydrogen fluoride	mg	5.2754207	0.69098668
Air	Hydrogen peroxide	ng	17.549143	22.957874
Air	Hydrogen sulfide	mg	4.377266	0.054040521
Air	Iodine	µg	7.5432556	30.821092
Air	Iodine-129	µBq	442.96152	174.84883
Air	Iodine-131	mBq	1.73E+01	8.46E+00
Air	Iodine-133	µBq	1.1505617	82.918997
Air	Iodine-135	µBq	1.2116832	179.30587
Air	Iron	µg	44.169669	51.042749
Air	Isocyanic acid	ng	450.45162	117.94564
Air	Kerosene	µg	170.03466	8.2191979
Air	Krypton-85	mBq	137.13366	66.915965
Air	Krypton-85m	mBq	9.3149317	4.0611325
Air	Krypton-87	mBq	3.244604	1.4765121
Air	Krypton-88	mBq	3.3931806	1.5139512
Air	Krypton-89	µBq	999.78086	427.14336
Air	Lanthanum-140	nBq	42.30847	17.760172
Air	Lead	µg	40.901688	37.26666
Air	Lead-210	mBq	2.2906555	13.058324
Air	Magnesium	µg	61.80698	47.301154
Air	Magnesium oxide	pg	-48.31562	548.28172
Air	Manganese	µg	90.066063	49.753896
Air	Manganese-54	nBq	3.9381469	1.6531485
Air	Mercaptans, unspecified	pg	-3.07E-06	2.06E-05
Air	Mercury	µg	15.613065	4.7359571
Air	Methacrylic acid, methyl ester	ng	3.5398383	3.0907069
Air	Methane, dichlorofluoro-, HCFC-21	pg	2.1585782	2.7149937
Air	Methane, tetrafluoro-, FC-14	ng	33.116166	54.880737
Air	Methyl acrylate	ng	7.3968473	9.6831513
Air	Methyl amine	pg	14.122788	18.420314
Air	Methyl borate	pg	0.002497028	0.003268838
Air	Molybdenum	ng	625.31822	525.41084
Air	Monoethanolamine	µg	362.92845	0.47711413
Air	N-Nitrodimethylamine	µg	1.4059843	0.067962986
Air	Naphthalene	ng	358.60326	17.334296
Air	Niobium-95	nBq	0.46749233	0.19624308
Air	NMVOC, non-methane volatile organic compounds, un	g	1.3208453	0.77320173
Air	Noble gases, radioactive, unspecified	kBq	4.2570279	1.681217
Air	Organic substances, unspecified	mg	1.9612229	0.094802314
Air	Ozone	µg	193.83707	123.52704
Air	Paraffins	pg	23.586282	5.8315772
Air	Particulates	mg	593.99027	28.71252
Air	Particulates, < 10 um	mg	22.498533	59.702156
Air	Particulates, < 2.5 um	mg	57.336111	15.141132
Air	Particulates, > 10 um	mg	66.113595	23.319404
Air	Particulates, > 2.5 um, and < 10um	mg	72.599332	7.8078998
Air	Particulates, unspecified	mg	0.2486343	5.8413609
Air	Phenol	µg	18.77923	224.6998
Air	Phosphine	pg	5.6352696	7.3770843
Air	Platinum	pg	4.808286	2.6169569
Air	Plutonium-238	nBq	0.06042712	0.023852219
Air	Plutonium-alpha	nBq	0.13852149	0.054678166
Air	Polonium-210	mBq	4.0246658	23.577046
Air	Polychlorinated dioxins and furans	pg	-0.70455545	43.860317
Air	Potassium	mg	1.7835786	0.16122395
Air	Potassium-40	mBq	0.52485139	3.3842645
Air	Protactinium-234	µBq	61.382608	66.933366
Air	Radioactive species, other beta emitters	Bq	0.006569608	32.025064
Air	Radioactive species, unspecified	Bq	9321.5768	450.58982
Air	Radium-226	mBq	2.5751148	4.6088988
Air	Radium-228	mBq	0.63476099	1.6425758
Air	Radon-220	mBq	21.567503	75.34031
Air	Radon-222	kBq	8.1093726	3.8743707
Air	Ruthenium-103	nBq	0.10271113	0.043115885
Air	Scandium	ng	10.373746	13.451542
Air	Selenium	µg	48.355361	9.80653
Air	Silicon	µg	156.64949	169.09676
Air	Silicon tetrafluoride	ng	11.609336	1.360482
Air	Silver	ng	1.6677848	0.88097055
Air	Silver-110	nBq	1.0179459	0.42731146
Air	Sodium	µg	133.03909	25.000794
Air	Sodium carbonate	ng	0.13872181	3.6147722
Air	Sodium chlorate	µg	15.720822	33.869677
Air	Sodium formate	ng	1.079534	0.86595594
Air	Sodium hydroxide	ng	65.413355	85.608289
Air	Strontium	µg	3.1474951	13.135262
Air	Sulfate	mg	3.3427363	0.64961557
Air	Sulfuric acid	µg	-87.39759	682.32182
Air	Terpenes	µg	0.006703455	16.408147
Air	Thallium	ng	25.876819	18.274056
Air	Thorium	ng	15.082287	20.020544
Air	Thorium-228	µBq	125.32665	586.72457
Air	Thorium-230	µBq	248.91822	429.61521
Air	Thorium-232	µBq	159.31251	858.53177
Air	Thorium-234	µBq	61.395497	66.943287
Air	Tin	ng	653.20557	686.59181
Air	Titanium	µg	3.1855092	4.0028885
Air	Uranium	ng	19.152254	26.232226
Air	Uranium-234	µBq	735.66945	697.97496
Air	Uranium-235	µBq	34.622911	16.54031
Air	Uranium-238	mBq	1.1328209	3.3902662
Air	Uranium alpha	mBq	3.3339459	1.590345
Air	Urea	ng	x	36.389684

Compartment	Substance	Unit	Disposable surgical gown and huck towel	Reusable surgical gown and huck towel
Water	1-Methylfluorene	pg	0.046647151	0.44919851
Water	1,4-Butanediol	pg	54.15613	70.635686
Water	2-Hexanone	pg	2.6721331	25.731865
Water	2-Methylnaphthalene	pg	6.4845299	62.444139
Water	4-Methyl-2-pentanone	ng	0.00572658	1.9525788
Water	Acenaphthene	ng	1.2613152	0.43974056
Water	Acenaphthylene	pg	78.882897	27.501457
Water	Acetic acid	mg	0.00065914	6.6223743
Water	Acetone	ng	70.835738	4.71719
Water	Acidity, unspecified	µg	495.09497	611.58868
Water	Acrylate, ion	ng	15.429776	20.198982
Water	Actinides, radioactive, unspecified	µBq	719.49241	284.00304
Water	Alkylated benzenes	pg	20.156176	194.09812
Water	Alkylated fluorenes	pg	1.1632993	11.202234
Water	Alkylated naphthalenes	pg	0.32940951	3.1721179
Water	Alkylated phenanthrenes	pg	0.137062	1.3198672
Water	Aluminum	mg	93.173078	33.652073
Water	Antimony	mg	2.1442957	0.13376943
Water	Antimony-122	nBq	294.001	123.41519
Water	Antimony-124	µBq	127.94032	47.945232
Water	Antimony-125	µBq	131.78847	44.576529
Water	AOX, Adsorbable Organic Halogen as Cl	mg	3.9294674	2.2546893
Water	Arsenic	ng	24.591998	135.69745
Water	Barite	mg	1.8498148	0.49878723
Water	Barium	µg	604.78542	349.23494
Water	Barium-140	µBq	1.2878805	0.54062411
Water	Benzene, 1,2-dichloro-	ng	18.207263	23.747683
Water	Benzene, chloro-	ng	375.96543	490.37079
Water	Benzene, ethyl-	µg	4.8692396	1.7421757
Water	Benzoic acid	ng	0.41579313	4.003967
Water	Beryllium	µg	2.0352109	3.1890941
Water	Bis(2-ehtylhexyl)phthalate	pg	93.906	0.031725106
Water	BOD5, Biological Oxygen Demand	mg	204.75642	412.81266
Water	Boron	mg	18.555971	1.0770368
Water	Bromate	µg	124.96354	398.76592
Water	Bromide	ng	87.765751	845.15868
Water	Bromine	mg	2.0419429	0.30364425
Water	Butanol	ng	42.526261	55.582224
Water	Butene	ng	93.139366	15.616857
Water	Butyl acetate	ng	55.283537	72.256212
Water	Butyrolactone	pg	94.031951	122.64566
Water	Cadmium	ng	1.5224744	55.061231
Water	Calcium	µg	147.70993	19.720694
Water	Calcium, ion	mg	174.77786	98.376964
Water	Carbonate	mg	6.9886114	0.58391808
Water	Carboxylic acids, unspecified	µg	873.05858	306.48024
Water	Cerium-141	nBq	514.91567	216.15032
Water	Cerium-144	nBq	156.75717	65.803232
Water	Cesium	ng	2.03E+02	70.697833
Water	Cesium-134	µBq	121.26963	40.015407
Water	Cesium-136	nBq	91.387478	38.362466
Water	Cesium-137	mBq	82.858531	32.691615
Water	Chlorate	mg	1.737785	3.0476987
Water	Chloride	g	0.38299491	1.9098251
Water	Chlorides	µg	14.742803	141.96891
Water	Chlorinated solvents, unspecified	µg	1.2636437	0.94642585
Water	Chlorine	mg	0.004254691	50.002325
Water	Chromate	µg	4.3668308	0.21108547
Water	Chromium	µg	80.577643	28.719703
Water	Chromium-51	µBq	167.63356	61.162469
Water	Chromium, ion	µg	6.7796485	6.1713405
Water	Cobalt	µg	64.7586	4.64E+01
Water	Cobalt-57	µBq	2.9009833	1.2177694
Water	Cobalt-58	mBq	1.1437091	0.418319
Water	Cobalt-60	µBq	906.06485	332.88281
Water	Copper	µg	-0.031534217	1.6397673
Water	Copper, ion	mg	2.1188832	0.20690673
Water	Crude oil	mg	1.27E-05	5.9605183
Water	Cumene	µg	4.2531425	718.05722
Water	Cyanide	µg	44.774586	6.7463552
Water	Cyanide (inorganic) compounds	ng	39.070259	23.053695
Water	Detergent, anionic	pg	-0.004921648	0.033079045
Water	Dibenzofuran	pg	7.79E-02	0.74977332
Water	Dibenzothiophene	pg	0.063117627	0.60780441
Water	DOC, Dissolved Organic Carbon	mg	179.50374	53.056629
Water	Ecoli organisms	p	x	333.102
Water	Ethanol	µg	0.097850665	2.1473394
Water	Ethene	µg	1.8619902	0.63353732
Water	Ethene, dichloro- (trans)	pg	87.69	0.029625099
Water	Ethyl acetate	ng	0.006670037	325.72899
Water	Ethylene diamine	µg	9.124976	1.58E-05
Water	Fluoride	mg	4.9034852	2.3210994
Water	Fluorine	pg	0.57358719	5.523478
Water	Fluosilicic acid	µg	1.0989416	0.57087129
Water	Glutaraldehyde	ng	228.37219	61.578671
Water	Hardness	µg	4.0542709	39.041451
Water	Heat, waste	kJ	26.837296	30.361697
Water	Hexanoic acid	pg	86.038079	828.5217
Water	Hydrocarbons, aliphatic, alkanes, unspecified	µg	2.64E+01	9.19E+00
Water	Hydrocarbons, aliphatic, unsaturated	µg	2.4334056	0.84837402
Water	Hydrocarbons, aromatic	µg	110.03731	38.32117
Water	Hydrocarbons, chlorinated	ng	-4.02E-08	515.33915
Water	Hydrocarbons, unspecified	mg	3.9273346	0.28419599
Water	Hydrogen-3, Tritium	Bq	190.12533	76.327347
Water	Hydrogen peroxide	µg	126.98476	0.19264326
Water	Hydrogen sulfide	µg	152.21738	17.786948
Water	Hydroxide	ng	493.90841	638.85306
Water	Hypochlorite	µg	8.9111213	7.517553
Water	Iodide	µg	21.159484	10.421647
Water	Iodine-131	µBq	24.230482	8.8915501
Water	Iodine-133	nBq	808.50274	339.39175
Water	Iron	mg	26.416972	1.2776497
Water	Iron-59	nBq	222.27469	93.30606
Water	Iron, ion	mg	28.180781	9.3064542
Water	Lanthanum-140	µBq	1.3716992	0.57580934
Water	Lead	µg	582.71103	67.332767
Water	Lead-210	mBq	5.7480704	150.03938
Water	Lead 210	pg	4.25E-08	4.09E-07
Water	Lithium	ng	0.43998054	4.2368847
Water	Lithium, ion	µg	1.4682436	500.62358
Water	m-Xylene	ng	0.053817013	14.228269
Water	Magnesium	mg	20.722511	11.560265
Water	Manganese	mg	18.381636	0.91069325
Water	Manganese-54	µBq	72.045436	25.760831
Water	Mercury	µg	9.5383947	1.287602
Water	Methanol	µg	7.7075339	6.3835259
Water	Methychloride	pg	0.016470476	0.15860589
Water	Methyl acrylate	ng	144.49957	189.16315
Water	Methyl amine	pg	3.39E+01	44.207981
Water	Methyl ethyl ketone	ng	137.5512	4.9105146
Water	Methyl formate	pg	11.451711	14.993325
Water	Molybdenum	µg	57.442683	19.673241
Water	Molybdenum-99	nBq	472.93242	198.52666
Water	n-Decane	pg	11.978528	115.34974
Water	n-Docosane	pg	0.43767697	4.2147021
Water	n-Dodecane	pg	22.690096	218.49903
Water	n-Eicosane	pg	6.231138	60.004048
Water	n-Hexacosane	pg	0.27297222	2.6286431
Water	n-Hexadecane	pg	24.763302	238.46341
Water	n-Octadecane	pg	6.104442	58.784003
Water	n-Tetradecane	pg	9.9283566	95.607189
Water	Naphthalene	pg	7.4635442	71.871762
Water	Nickel	ng	1.9692682	521.06558
Water	Niobium-95	µBq	14.618668	3.9480957
Water	Nitrogen, organic bound	µg	329.3545	108.61116
Water	Nitrogen, total	µg	24.454802	553.37857
Water	non-filtrable residue	ng	39.348628	65.209291
Water	Non-prescribed liquids	pg	-4.94E-05	0.000331883
Water	o-Cresol	pg	11.748171	113.13148
Water	o-Xylene	ng	0.030139897	10.27673
Water	o + p-Xyxlene	pg	9.029967	86.955959
Water	Oil and grease	ng	8.2928269	79.857513
Water	Oils, unspecified	mg	46.792486	6.8480866
Water	Organic substances, unspecified	mg	8.5166603	0.41168146
Water	p-Cresol	ng	47.96467	0.13820459
Water	p-Cymene	pg	0.040888244	0.39374191
Water	Paraffins	pg	68.4497	16.923806
Water	Pentamethylbenzene	pg	3.06E-02	0.29502915
Water	Pentanone, methyl-	ng	2.64E+00	1.74E-02
Water	Pesticides, unspecified	pg	x	644.17394
Water	Phenanthrene	pg	0.11632993	1.1202234
Water	Phenol	µg	509.02805	236.71915
Water	Phenol, 2,4-dimethyl-	pg	11.471744	110.46956
Water	Phthalate, diethyl-	pg	82.584	0.027900094
Water	Polonium-210	mBq	8.2439033	228.41223

Compartment	Substance	Unit	Disposable surgical gown and huck towel	Reusable surgical gown and huck towel
Waste	bauxite residue	mg	0.65868054	1.0915779
Waste	Iron	kg	x	x
Waste	Prescribed liquid waste	mm3	-7.97E-12	5.36E-11
Waste	Sodium hydroxide	ng	-0.21639996	9.9728593
Waste	spent potliner	µg	4.7687279	7.9028261
Waste	waste - CCA sludge	mm3	x	2.58E-09
Waste	Waste, mining	µg	-0.11638508	5.6683
Waste	waste, non-prescribed/m3	mm3	-2.24E-09	1.51E-08
Waste	Waste, nuclear, medium active	pg	-0.10739953	0.72184644
Waste	Waste, Tin	kg	x	x
Waste	Waste, unspecified/m3	mm3	x	0.010899671
Soil	2,4-D	µg	0.002709279	16.536307
Soil	Abamectin	ng	x	67.716336
Soil	Acephate	µg	x	64.546947
Soil	Aclonifen	ng	114.01772	2.1473353
Soil	Alachlor	µg	x	110.5464
Soil	Aldicarb	µg	x	49.981255
Soil	Aluminum	µg	172.96521	68.667979
Soil	Ammonia	ng	34.79084	18.785741
Soil	Antimony	ng	1.6690447	0.91437885
Soil	Atrazine	pg	43.999844	57.583676
Soil	Azoxystrobin	ng	x	515.93242
Soil	Barium	µg	62.265677	20.154957
Soil	Benomyl	ng	0.017202322	42.106378
Soil	Bentazone	ng	58.189374	1.0959005
Soil	Benzene, ethyl-	ng	25.179522	13.595992
Soil	Beryllium	µg	-0.70822114	83.42904
Soil	Bifenthrin	ng	x	56.429209
Soil	Boron	µg	2.4834573	4.2104793
Soil	Bromoxynil	ng	x	548.17222
Soil	Buprofezin	ng	x	257.9598
Soil	Calcium	mg	1.1075292	0.43474834
Soil	Carbetamide	ng	89.520501	0.41141985
Soil	Carbofuran	µg	0.009430968	23.600252
Soil	Carbon	µg	555.9595	260.69296
Soil	Carboxin	ng	x	24.183671
Soil	Carfentrazone ethyl ester	ng	x	677.16336
Soil	Chloride	mg	10.803614	1.032417
Soil	Chlorothalonil	µg	67.947684	0.023217508
Soil	Chlorpyrifos	µg	x	6.1910613
Soil	Chromium	µg	1.1986274	45.085924
Soil	Chromium (III) compounds	pg	304.96419	176.48689
Soil	Chromium, ion	µg	x	85.463001
Soil	Clethodim	ng	x	104.79848
Soil	Clomazone	ng	x	177.34757
Soil	Cobalt	ng	42.322851	28.513156
Soil	Copper	µg	5.4922841	178.16513
Soil	Cumene (1-methylethylbenzene)	ng	9.5416705	5.152142
Soil	Cyanazine	ng	x	499.81255
Soil	Cyanide (inorganic) compounds	pg	61.453438	33.182538
Soil	Cyclanilide	µg	x	4.6108637
Soil	Cyclohexane	ng	85.580058	46.210002
Soil	Cyfluthrin	µg	x	41.62604
Soil	Cypermethrin	µg	0.005283871	6.4518263
Soil	Deltamethrin	ng	x	96.735324
Soil	Dicamba	ng	x	161.22448
Soil	Dicofol	µg	x	40.666746
Soil	Dicrotophos	µg	x	21.281772
Soil	Dimethipin	ng	x	322.46178
Soil	Dimethoate	ng	x	274.08289
Soil	Disodium acid methane arsenate	µg	x	1.1930958
Soil	Disulfoton	ng	x	483.69267
Soil	Diuron	µg	x	44.242961
Soil	Endosulfan	µg	x	2.450639
Soil	Endothall	ng	x	64.492357
Soil	Esfenvalerate	ng	x	96.735324
Soil	Ethephon	µg	x	177.34757
Soil	Etridiazole	µg	x	1.1608239
Soil	Fenpiclonil	µg	2.6782993	0.000987869
Soil	Fenpropathrin	ng	x	257.9598
Soil	Fluometuron	µg	x	130.40918
Soil	Fluoride	µg	11.701309	21.456599
Soil	Glyphosate	µg	2.896933	538.94311
Soil	Heat, waste	kJ	1.1864338	1.8520408
Soil	Hexane	ng	226.30024	122.19359
Soil	Imidacloprid	µg	x	40.368496
Soil	Indoxacarb	ng	x	773.8826
Soil	Iprodion	ng	x	128.98151
Soil	Iron	mg	5.3584548	0.72849435
Soil	Lactofen	ng	x	120.92157
Soil	Lambda-cyhalothrin	µg	x	1.0641046
Soil	Lead	µg	-1.0887408	220.53205
Soil	Linuron	µg	0.87845005	1.3709181
Soil	Magnesium	µg	168.47795	63.133047
Soil	Malathion	µg	x	150.74335
Soil	Mancozeb	µg	88.250042	0.03015476
Soil	Manganese	µg	46.885716	18.508903
Soil	Mepiquat chloride	µg	x	9.867164
Soil	Mercury	µg	-0.007451735	3.2621695
Soil	Metalaxil	ng	x	451.45293
Soil	Metaldehyde	ng	34.252617	0.083412207
Soil	Methamidophos	ng	x	96.735324
Soil	Methomyl	ng	x	290.20598
Soil	Metolachlor	µg	6.3578856	12.695493
Soil	Metribuzin	µg	3.1073405	0.001061768
Soil	Molybdenum	ng	9.3233151	6.6161036
Soil	Monocrotophos	µg	x	39.884804
Soil	Monosodium acid methanearsonate	µg	x	94.147982
Soil	Naled	ng	x	709.40311
Soil	Napropamide	ng	60.600657	0.14757515
Soil	Norflurazon	ng	x	274.08289
Soil	Oils, biogenic	µg	721.29072	9.6291659
Soil	Oils, unspecified	mg	12.325016	4.867225
Soil	Orbencarb	µg	16.779947	0.005733655
Soil	Oxamyl	µg	x	3.0955305
Soil	Paraquat	µg	x	15.961249
Soil	Parathion	µg	x	3.9985002
Soil	Pendimethalin	µg	x	47.078393
Soil	Permethrin	ng	x	56.429209
Soil	Pesticides, unspecified	µg	x	47.814795
Soil	Phorate	µg	x	8.3839426
Soil	Phosphorus	µg	26.66	10.15995
Soil	Piperonyl butoxide	µg	x	39.884804
Soil	Pirimicarb	ng	5.504335	0.10366503
Soil	Polycyclic aromatic hydrocarbons	ng	52.124806	28.145428
Soil	Potassium	µg	157.22051	59.401457
Soil	Profenofos	µg	x	4.449665
Soil	Prometryn	µg	x	139.63155
Soil	Propargite	µg	x	1.1366441
Soil	Pyriproxyfen	ng	x	40.30612
Soil	Pyrithiobac sodium salt	µg	x	3.0955305
Soil	Quintozene	µg	x	5.5459448
Soil	Selenium	pg	541.38492	576.57997
Soil	Silicon	µg	194.81663	94.841547
Soil	Sodium	µg	649.05301	87.951082
Soil	Spinosad	ng	x	419.18107
Soil	Strontium	µg	1.2531471	0.40529367
Soil	Sulfur	µg	99.14901	43.389995
Soil	Sulfuric acid	pg	8.4529042	11.065616
Soil	Tebufenozide	ng	x	120.92157
Soil	Tebutam	ng	143.59543	0.34968458
Soil	Teflubenzuron	ng	207.15603	0.070784565
Soil	Thiamethoxam	µg	x	1.1285841
Soil	Thidiazuron	µg	x	8.2548551
Soil	Thifensulfuron-methyl	ng	x	161.22448
Soil	Thiram	ng	0.030518966	74.701726
Soil	Tin	ng	6.7737182	14.868194
Soil	Titanium	µg	2.8773976	1.1468877
Soil	Toluene (methylbenzene)	ng	60.265339	32.541009
Soil	Total Volatile Organic Compounds	ng	180.71817	97.580995
Soil	Tralomethrin	ng	x	96.735324
Soil	Tribufos	µg	x	60.944058
Soil	Trichlorfon	µg	x	39.884804
Soil	Vanadium	ng	82.36028	32.827575
Soil	Xylene	ng	139.60173	75.379665
Soil	Zinc	µg	46.847557	22.836378
Non mat.	Aluminium mass input	µg	220.77444	365.87158
Non mat.	Copper mass input	µg	-0.37961262	620.18238
Non mat.	Noise from truck km	mm	x	543.37827
Non mat.	show on tree	µg	0.64389212	164.35551
Non mat.	Softwood Plantation Indicator	g	x	6.5272174
Non mat.	Steel mass flow	mg	-0.34284343	47.311961
Non mat.	Truck travel distance, urban	m	11.063165	18.847297
Non mat.	waste to landfill	g	284.49998	35.615949
Non mat.	Water discharged to sewer l	cu.in	x	290.38766

Appendix G Summary inventory

A summary inventory of substances contributing greater than 5% to an impact category has been compiled in Table Appx. G-1. Substances contributing to carcinogens and minerals (impact indicators) have been excluded from the table for clarity, as these amounts are extremely small in this study.

Table Appx. G-1 Inventory of substances contributing greater than 5% to any impact indicator (excluding carcinogens and minerals*).

	Amounts per functional unit		
Substances contributing greater than 5% to an impact category (excluding carcinogens and minerals*)	Disposable surgical gown and huck towel	Reusable surgical gown and huck towel	unit
Carbon Dioxide to air	1.00E+00	4.85E-01	kg
Carbon monoxide to air	2.03E-03	6.15E-04	kg
Nitrogen oxides to air	3.58E-03	2.58E-03	kg
Sulphur dioxide to air	1.08E-03	2.28E-04	kg
Sulhpur oxides to air	4.43E-03	9.98E-04	kg
Phosphorous to water	1.05E-05	2.81E-05	kg
Land occupied	2.38E-05	1.73E-06	Hectare years
Water	1.37E-02	1.12E-02	kilolitres
Solid waste	3.44E-01	4.32E-02	kg
Coal - black	1.95E-01	9.43E-03	kg
Coal - brown	3.44E-03	1.58E-01	kg
Natural gas	1.54E-01	1.44E-01	cubic meters
Crude oil	2.53E-01	1.63E-02	kg

* Mineral and carcinogen amounts extremely small in this study.

Appendix H Peer reviewer comments.

Section	Comment	Action
1	Please include a section where the involved parties are described in terms of commissioning party, contacted stakeholders.	Included Section 1.1 describing involved parties.
1	Please include a section related to ISO 14044 standard on comparisons for external communications and how the stakeholder procedure and third party review were applied, what results came from it, and how they are dealt with in the report.	Included Section 1.2 describing ISO 14044.
1.1	The referenced ISO 14044 is outdated, there is a newer one, please update	Reference date corrected.
1.2.1	I was a bit confused with the distinction of local and foreign impacts; I usually refer to them as local, regional and global impacts.	In Section 2.4.1 local, regional, global language used.
1.2.3	Did you test the assumption that capital goods for transportation is indeed minimal, or is there a reference used for this assumption?	Added capital goods inclusions and exclusions described in detail in Section 2.4.3.
1.3	What would be 'use'? I can see use not to be different for both alternatives, but at the same time easy to model. Why exclude it?	Use phase has been included.
1.5	Are there differences expected from applying the more stringent European requirements between the types of gowns, if so, this should be stated, if not, please state it is not. Just to theorise: Say the reusable one complies in all situations, but the disposable one need to be thicker, that is a difference that needs to be mentioned.	Added description of possible impacts in Section 2.5.
1.5	Please include a statement whether the other performance characteristics do or do not have an expected environmental relevance.	Added statement regarding other performance characteristics in Section 2.7.
3.1	Can you describe the representativity of the one laundry facility in terms of the Australian market using the general data quality indicators from ISO to obtain a feeling about what types of laundry facilities are included and which are not.	Added Section 4.1 describing data quality.and comments as to further research directions and how the data addresses goal and scope.
3.1.2	Including European manufacturing data is understandable, however, probably an underestimation of the environmental burdens for production in China. Did you try to correct for this lack of regional data, by for example over estimating the use of energy en the emission by 10% and adapting the electricity mix to a Chinese one, which relies heavily on coal and will influence the results on a mass to mass basis for European polyester vs. Chinese polyester?	Included manufacturing data based on Chinese manufacture, or used European manufacturing processes modified to coal based electricity grid. Updated table in Section 4.2.2 to reflect.
3.1.6	Is there a percentage available, that can then be related to the reuse rate	Reuse rate updated to reflect actual inventory purchases.
	Is the autoclave boiler efficiency an industry average, a best-case, a worst-case, …. Can you specify?	Boiler efficiency reflects typical average boiler efficiency.
	Did you test the modelled energy use by	Aggregated energy and water check

Section	Comment	Action
	comparing it to annual consumption figures for the laundry facility as a first step to test its validity? Or, did you define a different check?	added in Section 4.2.11.
3.2	Please remove further from the last sentence above 3.2.1	Corrected.
3.2.2.	How representative is this manufacturing route for Australia in terms of market share, if not the predominant one, why was this one chosen and what would be the others?	Manufacturing route known to be correct for gown analysed. Other gowns could be made in Asia, however electricity impacts would be expected to be similar to Americas. Transport distances would be shorter, however transport impacts not see not be critical to overall impact of disposable gown.
3.2.6	Isn't the incineration relevant for both types of gowns? Why only mention it here? How often does contamination occur in terms of a percentage? If this is less than 1% I can see that you just state this, if it is more, than it should be included in the default waste scenarios, and the number of reuse cycles for reusable gowns need to be changed accordingly.	EPA requires disposal of gowns to incineration only in certain, specific, circumstances. Disposal split is not known, however expect that higher costs associated with incineration would make it a less preferable option, with most gown going to landfill. Incineration is not relevant to reusable gowns which are all disposed of to landfill at end of life, once laundered. Incineration of disposable gowns is included as a sensitivity study.
Figure 5.1	Why did you not include a graph using the non-normalized results, they are much easier to read identifying the major drivers in any given environmental impact category. Could you include it? (everywhere)	Agree. Characterised results used for balance of reporting.
Figure 5.2	I do not understand where the negative numbers come from. Why are there values of less then zero in the graphs, where do we have savings? This is not clear and needs to be specified. In 7.2. you mention heat recovery, is that the key here? If so, why is this a saving, assuming you used consumption data for the water heater. It might already be included.	Benefits shown on this chart come from the water recycling process that recovers both water and energy. The total characterisation figures shown incorporate recycling benefits. To help clarify this, diagrams have been added to Section 6.1 to show how the recycling process provides benefits. Recycling benefits shown are not incremental to the characterisation data shown.
5.1	Please include the way you modelled reuse in chapter 3 as well, it is a surprise here. That is not good reporting. It should be part of system boundaries where you address allocation issues. Also, there are more allocation items that need to be specified. Please add a section on allocation.	Added Section 3.4.2 and discussion in Section 4.2.2. Added discussion of co-products.
5.1	How did you get to the number of 200 life cycles? I need to have a justified number here. Just mentioning is not enough. Different ways of modelling reuse exist. What was the leading argument here to include 1/200? If this were to apply to steel and aluminium and plastics this would erase all environmental impacts associated with primary production. Since they have an impact is seems strange to use this kind of reasoning. The main reasoning here is	Life cycle based on anecdotal evidence from laundry operator and gown manufacturer. Improved estimate developed based on inventory top-up and annual processing. Refer Section 4.2.2. On average, gowns last 3.7 years and undertake 127 cycles before disposal.

Section	Comment	Action
	the extended time horizon, which might not apply to gowns. Another approach could be to look at the recovery rate, how many reusable gowns are recovered out of a used batch, in other words, how many do not make it to the laundry facility + how many do not make it out of the laundry facility. Sat this rate is 95% then we are talking about, 200 cycles means a recovery and reuse rate of 99.5% That seems high. How can you convince me, and what would be a good design for a sensitivity analysis.	
5.1	Is there a difference in reuse efficiency between the gown and the huck towel? Probably, since the material is different. This does not seem to be addressed. Please clarify.	No data was available on huck towel reuse rates. Study assumes simpler construction and simpler wear characteristics would likely lead to longer life than gown, however this could not be proven. Hence assumption of similar life to gown.
Figure 5.5	From figure 5.5. I read that you included the way EcoInvent models energy use and sequestration of CO2 during the production of biomass materials. This is one way to do it and has raised discussion in the LCA community. I do not want to choose sides, but including sequestration during the growth phase, means you have to include emissions during the final waste treatment, to the same extend. I am not sure whether this was done in your case. The same applies to the energy from biomass. Can you tell me how this was modelled in a consistent way for both products? It refers to the flows energy in biomass and carbon dioxide in air that are modelled as inputs from nature. It is in both paper and cotton. They are not included in Appendix C. That is inconsistent. And, there seems to be a benefit related to carbon sequestration associated with landfill of paperboard, I would expect the opposite. Can you clarify this?	Reviewed impact assessment and assimilation affects during biomass growth phases are not included. A small sequestration of carbon in landfill is assumed, concistent with US EPA studies.
5.3	The second paragraph includes the word ‘bunch’, please change the language to a more neutral position.	Spelling error. Corrected.
Figure 6.1	Why do you use the normalised results? It is far more difficult to read the using the non-normalised graphs.	Agree. Characterisation used in remainder of report.
6.1	Is there any evidence suggesting that the scenarios as being wost-case/plausible/most likely, best-case,… Please include a statement like this to inform the reader about what is actually modelled.	Scenario classification added.
6.4	What system boundaries are used for recycling benefits? Please include this in the chapter with system boundaries and allocation.	Added Section 3.4.1.
7	Are there any remarks to be made about the	Added remark in Section 8.

Section	Comment	Action
	extend of the studies as far as they do or do not compare with the depth and detail of the current study under review? That would assist the reader in reading and valuing the results.	
7	Please include a sensitivity analysis for the use of high P detergent	Added, along with reference in Limitations, section of conclusion.
8.1	Interesting thought for the reusable gown industry: Why not supply a paper huck towel with the reusable gown just as the disposables?	Despite a high manufacturing impact, the reusable huck towel still has a lower impact per cycle in most indicators.
10.1	Bulwal is Buwal	Removed datasets not used in this study.
10.1	Industry data is available in version 2.0	Removed datasets not used in this study.
10.1	IVAM database is available in version 4.0, which one is used here?	Removed datasets not used in this study.
10.1	Which processes are used from Buwal, Industry data and IVAM, since they are not referenced anywhere else in the report, but here.	Removed datasets not used in this study.
App B	Which producers were surveyed? What is their aggregated market share?	3 major producers were surveyed that are major sellers in the Melbourne marketplace. It is not known what proportion of the total Australian market they represent.
App B	I can not related the solution for the remark 'Country of manufacture should be in Asia not Americas' back to the report, how has this been dealt with?	Asian manufacture not included, however do not expect significant change in study outcome. Transport not a major driver of impacts and electricity impacts expected to be similar to Americas.
App B	The remark 'Country of manufacture should be in Asia not Americas' seems strange, didn't you use the most recent study from Plastics Europe for all the plastic data? For PP specifically the last calculation was done in March 2005. I assume you used these (http://lca.plasticseurope.org/main2.htm)	Polypropylene from Ecoinvent 2.0 (2007), based on Plastics Europe 2005 release.
App C	I would like to see an additional sensitivity analysis using global normalisation factors from Sleeswijk et al., 2007, Normalisation in product Life Cycle assessment: An LCA of the Global and European Economic Systems in the year 2000	I like this idea, but I'm struggling to execute due to differences in characterisation units from those identified in Sleeswijk. We should discuss.
	Please check the normalisation factors for photchemical oxidation and solid waste. The devision of the annual normalisation data with the per capita data is different as compared to the other environmental impact indicators. This will change the relative impact per capita in the report with a factor 10.	Checked. Have removed annual normalisation factors from the study, as these were not used in the study, and were incorrect for eutrophication. Per capita data were checked and found to be correct.
App D	Missing; non-classified substances. Most non-classified substances that could be classified have been added to the methodology during the review. However some minor substances seem to be missing. We recommend to check this for general purposes.	Added
App E	Missing: overview of LCI for the two product alternatives for the functional unit	Added

Peer reviewer letter:

RMIT University
Centre for Design
Attn. Andrew Carre
GPO Box 2476V,
Melbourne, Victoria, 3001 Australia

Date
November 28, 2008

Your reference
-
Our reference
08.0130-L08.0075
Concerning
Peer review life cycle assessment comparing laundered surgical gowns with polypropylene based disposable gowns

Dear Andrew Carre,

RMIT has asked theRightenvironment to conduct a peer review according to the ISO guidelines laid down in the ISO standard 14044:2006, “Environmental management – Life cycle assessment – Requirements and guidelines” on a LCA study comparing laundered surgical gowns with polypropylene based disposable gowns, prepared by Andrew Carre, dated 5 November 2008.

After receiving the draft report, RMIT and theRightenvironment shared several rounds of feedback before the final review took place. The topics discussed are included in appendix H of the final report.

TheRightenvironment concludes that:
- the methods used to carry out the LCA are consistent with the ISO 14044:2006,
- the methods used to carry out the LCA are scientifically and technically valid,
- the data used are 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.

One remark we would like to make is the following. The default lay-out of the LCA for reusable gowns has well reported and sound definitions of several parameters. However, some parameters reflect a best-case for the industry. This is particularly true for the use of a water recycling system and low phosphate detergent. This is not practiced in all laundry facilities. Failure to do so will influence the outcome of the comparison: the values for water use and eutrophication will go up. This will not change the overall conclusions, although a more balanced comparison will result from it.

It can be considered good practice to use the worst-case for the commissioning party and best-case for the compared stakeholder that was more remotely involved and use the improvement options for sensitivity analyses. This would mean a reverse of the lay-out of the report. There is another reason to emphasize this: the compared disposable gown industry did not actively participate. This is not the fault of the LCA practitioners, they have tried to engage the industry. The reader should be aware of this.

We would like to thank RMIT for the open discussions we shared and hope our review has contributed to the overall quality of the study.

Yours sincerely,

J. Meijer
President.