Life Cycle Assessment of AbitibiBowater's Equal Offset Paper compared with Uncoated Freesheet

REPORT TO THIRD PARTIES
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ÉCOLE POLYTECHNIQUE MONTRÉAL

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ABSTRACT

This report summarizes the life cycle assessment (LCA) of AbitibiBowater's Equal Offset™ (EO) paper compared to Uncoated Freesheet (UFS) paper, when used for similar applications. The study was commissioned by AbitibiBowater in order to objectively address the environmental strengths and weaknesses of EO paper. The characterization methodology used was IMPACT 2002+, where an impact comparison was made in 15 categories of environmental impact. Out of 15 environmental impact parameters, the environmental impact of EO was found to be more than 50% less than that of UFS in 5 categories and from 25 to 50% less in another 5 categories. In 4 of the remaining 5 categories, the impact difference was less significant.

INTRODUCTION:

The study was carried out by Professor Paul Stuart and Dr. Matty Janssen in the Department of Chemical Engineering of École Polytechnique at the Université de Montréal.

There are four distinct steps to an LCA:

1. Define the goal and scope
2. Collect an inventory of inputs and outputs of the processes involved in making, using and disposing of the product
3. Evaluate the potential environmental impacts associated with the inputs and outputs found in the inventory.
4. Interpret the results of the impact analysis

In addition, a systematic and critical review of the LCA was carried out by external experts in order to ensure the study results were objective and followed accepted LCA methodology.

1a. GOAL OF STUDY

This LCA study compared the environmental impacts of two 100% virgin fiber paper product alternatives: Uncoated freesheet (UFS), produced in the southern United States and Quebec, and AbitibiBowater's Equal Offset™ (EO) paper, produced in Alma, Quebec[1], that provide a specific printing surface for the application of offset printing, using LCA methodology. This was done to provide AbitibiBowater's customers with a credible, science-based evaluation of the environmental life cycle impacts of EO paper compared with typical UFS paper.

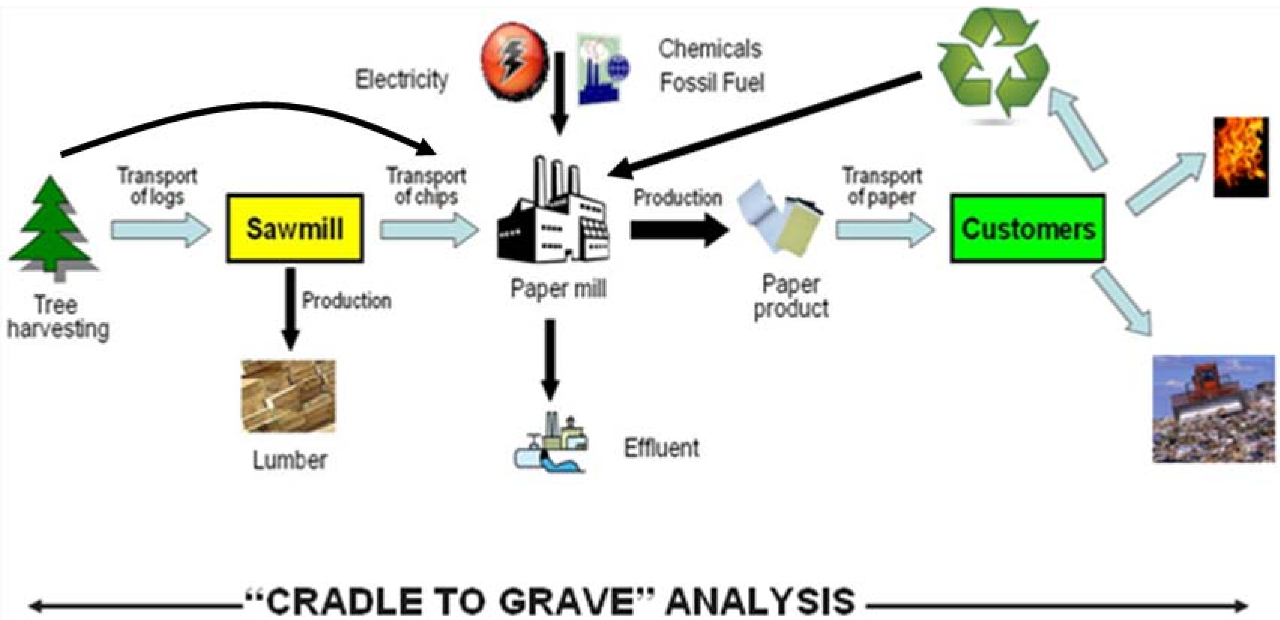
[1] The original study performed by Ecole Polytechnique included EO paper also made at our Beaupré, QC location, but this facility was closed in October 2009.

1b. SCOPE OF STUDY

Equal Offset™ paper is sold as a lighter-weight substitute for UFS in offset printing applications. The function of both products is to provide a paper printing surface for the application of offset printing. Customer experience has shown that the products can be used interchangeably and the print quality of EO is at least as good as UFS. The functional unit chosen was 500 sheets of 8½ x 11 inch sheets of paper, or 30.16 square meters of printing surface. In the case of EO, the weight of the functional unit is 1.89 kg; in the case of the UFS its weight is 2.23 kg.

For this cradle to grave analysis, as shown in Figure 1, inputs included wood fiber from the forest, chemicals, fuels and electricity. Outputs included air emissions, liquid effluent and solid wastes, as well as product disposal at end of life. Transportation at each stage of the life cycle was included. The only stage that was excluded from the analysis was the product use by the printer and end user. Since this was a comparative analysis, and both products are handled by the same customers in the same way for the same purpose, there would be little if any difference in impact from the use phase.

Figure 1: Life Cycle Stages for both products



2. LIFE CYCLE INVENTORY ANALYSIS:

Data for the EO life cycle inventory came from the AbitibiBowater mill producing this product in Alma, Quebec. Most of the data were from 2006, although in some cases 2007 data were used (due either to unavailability of 2006 data or because the 2007 data were more representative of the present situation). For the two UFS mills, production, raw material use and energy usage data were taken from the RISI Cornerstone database [1], and environmental output data came from the US Environmental Protection Agency's Toxics Release Inventory [2] and Environment Canada's National Pollutant Release Inventory [3]. Data relating to upstream processes (chemicals production, electricity and fossil fuel production and use, and forest operations) and processes for which it was difficult to obtain primary data were completed with data from the ecoinvent database [4]. Cut-off criteria for inclusion or exclusion of processes and flows were based on experience from previous studies (see e.g. [5]).

EO paper is manufactured in the AbitibiBowater facility in Alma, Quebec. Wood fiber is supplied to the mill as 100% chips from sawmills. The pulp for this paper is 100% softwood mechanical pulp, and the bleaching is done with a hydrogen peroxide bleaching process.

Two UFS mills were chosen, one in Quebec and one in the southeastern US, both large manufacturers of UFS, to represent a typical UFS product. Wood fiber is supplied to the mills as both logs and chips. The pulp for this paper is 100% virgin chemical pulp. The inventory results were a weighted average of the annual production of UFS from these two mills.

To account for the impacts of transportation to the paper mill's customer, a hypothetical customer was chosen in the state of Virginia. This customer would receive the paper in rolls at its printing plant and distribute the printed product to its customers.

In the end-of-life scenario, although some recycling will occur, all the material will ultimately be eliminated, either by landfill or by incineration. In this case, it was assumed that 80% of the material was eliminated by landfill, and 20% of the material was eliminated by incineration, based on a previous analysis [5].

Life cycle inventory numbers were calculated as the amount of substance associated with the functional unit in each case. All data obtained from primary sources were assumed correct. Secondary data were completed with data from the ecoinvent database [4]. Operations upstream of sawmilling were allocated to lumber and wood chips (for pulp production) according to their mass ratio. A sensitivity analysis was later done to observe the impact of allocation to lumber, wood chips and wood waste. In Table 1 are listed some of the major mass and energy flows calculated per functional unit.

Table 1: Major differences in the two products, per functional unit

	Equal Offset	**Uncoated Freesheet**
Weight of functional unit, kg	1.89	2.23
Moisture Content, %	6.5	6.5
Filler and coating content, %	20	18
Pulp content, %	73 (TMP)	76 (kraft)
Pulp yield, %	93	47(softwood), 49 (hardwood)
Transportation of raw materials, t-km	1.5	5.4
Transportation, product delivery, t-km	3.0	3.2
Fossil fuel energy, MJ	8.9	15.0
Biomass fuel energy, MJ	0.5	11.5
Electrical Energy, kWh	5.0	1.0

3. LIFE CYCLE IMPACT ASSESSMENT

The impact assessment was carried out using the IMPACT 2002+ characterization method [6]. In this method, the inventory results are linked via several midpoint categories to four damage categories (human health, ecosystem quality, resources and climate change). In this study, only the midpoint categories were used. The following 15 mid-point impact categories were considered in this analysis:

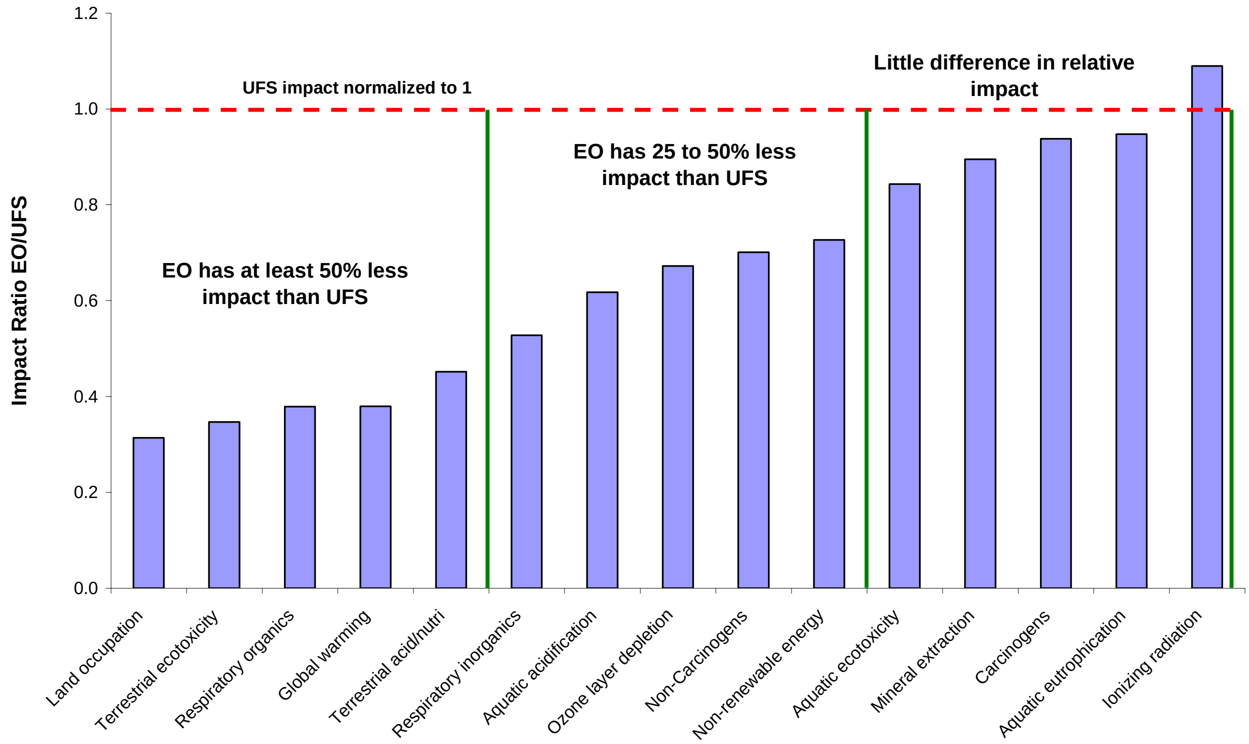
- Land occupation (Impact of the occupation of an area on plant species)
- Mineral extraction (Energy required to process mineral ore)
- Terrestrial eco-toxicity (Impact of substances in soil on plant and animal life)
- Terrestrial acidification & nutrification (From inorganic deposits such as sulfates, nitrates and phosphates)
- Global warming (Effect of greenhouse gases in the atmosphere)
- Use of non-renewable energy (Energy sources that are non-renewable)
- Respiratory effects (organic) (Respiratory effects from volatile organic compounds)
- Respiratory effects (inorganic) (Respiratory effects from particulates and inorganic substances such as SO_2)
- Aquatic acidification (Releases to water of substances such as sulfates, nitrates and phosphates)
- Aquatic eco-toxicity (Toxic materials released to water such as heavy metals)
- Aquatic eutrophication (Release of nutrients to water)
- Carcinogenic emissions (Potential impacts of release of carcinogenic substances)
- Non-carcinogenic emissions (Potential impacts of release of non-carcinogenic substances
- Ozone layer depletion (Impacts of uv radiation caused by emissions of ozone-depleting substances)
- Ionizing radiation (Impacts from releases of radioactive material –mostly from nuclear power)

All calculations were handled by Simapro 7 LCA software provided by Pré Consultants [7].

The results of the impact analysis for the EO and UFS paper products were compared per functional unit by normalizing the UFS result with the EO result for each midpoint category (UFS paper = 1). This allows direct comparison of the **relative** impact in each impact category. It does not provide a comparison of the relative overall impact of different categories, or express an absolute environmental impact of the products.

The results are summarized in Figure 2, and details are given in the Appendix. The y-scale indicates the ratio of the impact of EO to the impact of UFS. The red, dotted line indicates a ratio of one, i.e. the normalized impact of UFS. As can be seen from this graph, for the first five categories on the left-hand side, the impact of EO is less than half that of UFS. For the next five categories, the impact is 25 to 50% less for EO. For the next four categories, the impact is up to 25% lower for EO. The last category, ionic radiation, is an indicator of nuclear power in the electricity grid. Quebec has 4% nuclear power, whereas the US mill has none. Further interpretation of these results is given in section 4.

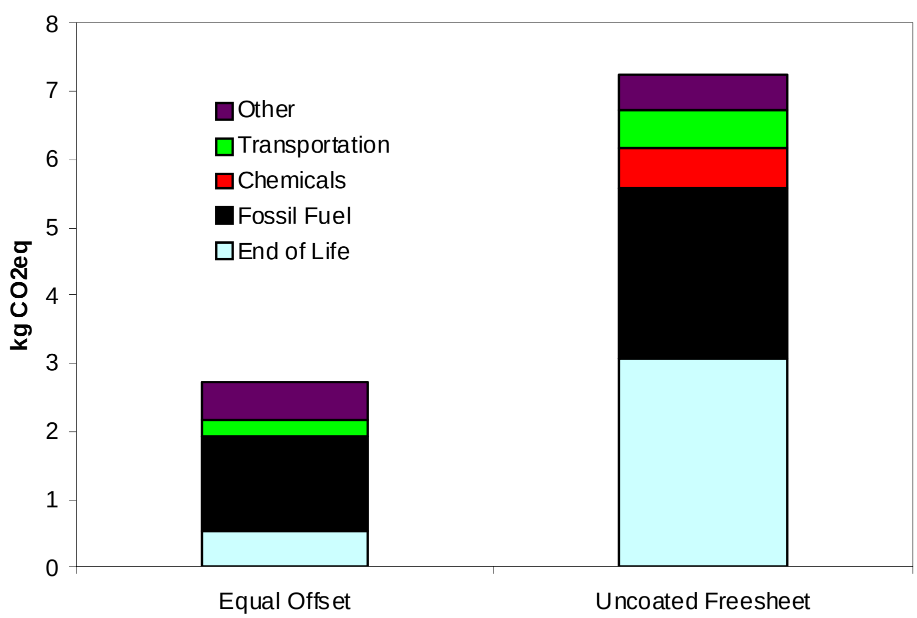
Figure 2: Relative Life Cycle Impact of Equal Offset compared to Uncoated Freesheet



Global warming

Of particular interest to many paper customers is the global warming category, or greenhouse gas (GHG) emissions. Shown in Figure 3 is a comparison of the two products, showing the break-down of the processes that contributed to GHG emissions during the life cycle. It was found that EO emits only about 38% of that of the UFS on a cradle-to-grave basis.

Figure 3: Contribution of Processes to life cycle greenhouse gas emissions for EO and UFS (per functional unit)



Scenario Analyses

In order to evaluate the impact of some of the modeling choices made, an analysis of three scenarios was carried out.

1. Inclusion of wood waste: In the original model, the environmental impacts caused by sawmill operations were only allocated to lumber (39%) and wood chips (61%). The case of allocation to lumber (30%), wood chips (47%) and wood waste (23%) was considered, since wood waste is used as a significant source of fuel in the two UFS mills. The results showed a decrease in the EO/UFS impact ratio for land occupation from 0.32 to 0.28. All other impact ratios changed by less than 4%.

2. Lignin in landfill: According to studies of methane generation in anaerobic landfills reported in the literature [8], products made of mechanical pulp, such as newsprint, degrade much less than office paper made of chemical pulps. This is thought to be due to non-reactivity of lignin in the decomposition reactions, as well as “protection” of some of the cellulose. Further analysis by the US EPA estimates that 85% of the carbon in newsprint remains intact, compared to only 12% in office paper [9]. The EPA methane emission results were incorporated into the base Simapro model, and this was compared this to the situation where both products would decompose at the same rate in the landfill, using the ecoinvent default model for anaerobic landfills. The results showed that the global warming and respiratory organics categories are affected. Without the differential treatment of methane production from the landfill, the EO/UFS impact ratio for global warming would change from 0.38 to 0.56 and the ratio for respiratory organics would change from 0.38 to 0.71 (due to the respiratory effects of methane released to the atmosphere).

3. Land use: tree growth rate in the southern US is about twice that in Quebec, and this was not considered in the model. Our analysis looked at the difference between the two locations. This was modeled by reducing the forest area needed to grow 1 m^3 of softwood/hardwood by 50%.

Based on weighted averages of the impact at all mills, the EO/UFS impact ratio for land occupation increased by 10%, indicating that a faster tree growth cycle has a positive impact on the environmental performance of the UFS mill in the southern US (the models for the other mills did not change in this analysis).

4. INTERPRETATION OF RESULTS

EO is made with mechanical pulp, which has a high yield, and is bulkier than freesheet made from chemical pulp, thus using fewer trees for the same area of paper. This significantly affects many of the categories in the impact analysis, such as land occupation for forestry, and categories affected by transportation, because there is less transportation of raw materials. In UFS, there are also more chemicals used in the pulping and bleaching processes, and the environmental footprint of these chemicals contributes to some of the differences observed. Fossil fuel use is also an important factor; this is partly due to the fuel used for steam production, and partly because electricity production in the Quebec mill producing EO paper is 95% hydro-electric, whereas more fossil fuel is used at the US mill for electricity production. Table 2 gives an approximate break-down of the process contributions to the impact categories with the largest differences.

Table 2: Contribution of processes to major impact differences

	Largest influence	2nd largest	3rd largest	4th largest
Land occupation	Forestry (59%)	Chemicals production (30%)		
Terrestrial ecotoxicity	Ash from boilers (31%)	Chemicals production (26%)	Transport to mill (20%)	
Respiratory Organics	End of Life (78%)	Transport to mill (8%)		
Global warming	End of Life (57%)	Fossil fuels –steam & power (23%)	Chemicals production (13%)	Transport to mill (7%)
Terrestrial acidification/nitrification	Boiler emissions (28%)	Transport to mill (26%)	Fossil Fuel –steam & power (18%)	Chemicals (13%)
Respiratory inorganics	Boiler emissions (33%)	Transport to mill (24%)	Fossil Fuel –steam & power (14%)	
Aquatic acidification	Fossil Fuel –steam & power (35%)	Chemicals production (29%)	Boiler emissions (10%)	

Note: percentages quoted are the % contribution to the total impact difference. For example, for global warming, shown in Figure 3, the total impact difference is 4.5 kg CO_2 equivalent.

Here are further explanations of these differences:
Land occupation: More trees are used for UFS due to the lower pulping yield. Also, due to higher starch content, more farmland is required for cultivation of corn and potatoes.
Terrestrial ecotoxicity: This category involves substances released to the soil, such as heavy metals, that affect plants or animal life such as worms in the soil. Ash from the boilers, corn farming operations and transportation differences are contributing processes.
Global Warming: The largest effect is for end-of-life, as explained under sensitivity analysis no. 2 above. The UFS used more fossil fuels (at the mill or in production of chemicals and electricity), and there was a higher transportation factor.
Respiratory Organics: Methane released from the landfill was the largest factor and transportation was also significant.
Terrestrial acidification/nitrification: This category comes from the effect of deposition of inorganic substances such as sulfates, nitrates and phosphates in soil. The UFS releases more sulfur and nitrogen from the boiler, uses more overall fossil fuels in the life cycle (including transportation) and there are also effects from corn farming.
Respiratory inorganics: This is due mostly to airborne particles, SO_2 and NOx from combustion. The UFS released more from boilers, transportation and overall use of fossil fuels in the life cycle.
Aquatic acidification: This can be mostly attributed to the use of coal in the southern US mill, and the use of starch, sulfur and sulfuric acid in UFS.

The reason for EO having a slightly higher impact than UFS in Ionic Radiation is that Quebec's power grid is 4% from nuclear energy whereas the US UFS mill has no nuclear power in its grid.

Assumptions and Limitations

The LCA was performed for Equal Offset paper, produced at AbitibiBowater's Alma paper mill, and the inventory data are taken directly from production records. The impact numbers for EO are thus reliable. For the UFS production, because there are no data available to represent the entire North American industry, two mills were chosen to represent it that are large producers of UFS for printing and converting grades. The results of the LCA comparison could change somewhat based on the individual profile of the UFS mill(s) chosen, but some things, such as the chemical usage and pulping yield, would not vary significantly in comparison to the EO producers. The data sources are purchased third party databases, therefore the accuracy of the data is dependent on these mills having provided the correct data to these parties.

AbitibiBowater believes that the findings of this LCA analysis should be similar, but not identical, to other AbitibiBowater UFS substitute products produced in Alma, such as Alternative Offset, ECOPAQUE™, ECOLASER™ and ECOPAQUE LASER™, since the manufacturing process is the same, and differences in product recipe are due to the amount and formulation of coating, which is a relatively minor component of the environmental impacts.

The findings cannot be applied directly to UFS substitute grades of paper made at other AbitibiBowater production facilities, such as Alternative Offset from Fort Frances, ON or AbiBowHYBRID grade from Calhoun, TN.

5. CRITICAL REVIEW

A peer review of this study was carried out in order to validate the findings by an independent third party. This review was carried out by CIRAIG (the Interuniversity Research Centre for the Life Cycle of Products, Processes and Services). The panel of experts consisted of:
Mike Bradley, Director Technology and Sustainability, Canfor Pulp L.P.
MariaWellisch, Research Advisor, Natural Resources Canada
Jean-François Ménard, Senior Analyst, CIRAIG

Much of the feedback from the reviewers focused on the wording of findings and conclusions, and on clarification of issues. Appropriate corrections were made in response to this feedback. In addition, here are some of the specific issues raised, and École Polytechnique's response:

	Reviewer comment	**Response**
1	Exclusion of the paper use phase prevents the establishment of complete environmental profiles.	Lack of data prevented us from looking at the use phase, but the main goal of the study was a comparative analysis, and the impact of the use phase should be similar for both papers.
2	What about the effect of recycling of the product before reaching the disposal phase?	There is no reason to assume any difference in recycling rate of the two products.
3	Which studies included human activities and infrastructures and showed these to be negligible?	Much of the work to build a basic pulp & paper LCA model and determine which processes to include or exclude was done previously at École Polytechnique. Reference 5 was added.
4	The SimaPro model itself was not reviewed by any of the reviewers.	No, but AbitibiBowater had a chance to review the model, and found a few small errors in the calculations, which have been modified accordingly.
5	The mills with cogeneration should be treated appropriately to allow allocation to electricity and heat co-products	All produced energy was used onsite in these mills, therefore it is all allocated to the paper.
6	The land occupation category is not a fair comparison when comparing natural forest (in Quebec) with plantation forest (in the US UFS mill). Results should clarify and explain this.	We included a sensitivity analysis for the faster growth cycle in the US plantation forest. We also broke out the process contributions to the land occupation category, showing that the large difference between the two products is attributable in part to the farming of corn.

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APPENDIX:

Impact Results from SimaPro Modeling

Impact category	**Unit (per functional unit)**	**Equal Offset**	**Uncoated Freesheet**	**Ratio EO/UFS**
Land occupation	m^2eq organic arable land.yr	0.34	1.09	0.31
Terrestrial ecotoxicity	kgeq triethylene glycol into soil	62	178	0.35
Respiratory organics	kgeq ethylene into air	0.0017	0.0045	0.38
Global warming	kgeq CO2 into air	2.7	7.2	0.38
Terrestrial acid/nutri	kgeq SO_2 into air	0.05	0.12	0.45
Respiratory inorganics	kgeq $PM_{2.5}$ into air	0.0028	0.0054	0.53
Aquatic acidification	kgeq SO_2 into air	0.0079	0.0128	0.62
Ozone layer depletion	kgeq CFC-11 into air	2.4E-07	3.5E-07	0.67
Non-Carcinogens	kgeq chloroethylene into air	0.20	0.28	0.70
Non-renewable energy	MJ primary non-renewable	32	44	0.73
Aquatic ecotoxicity	kgeq triethylene glycol into water	92456	109608	0.84
Mineral extraction	MJ surplus	0.022	0.024	0.90
Carcinogens	kgeq chloroethylene into air	0.061	0.065	0.94
Aquatic eutrophication	kgeq PO_4^{3-} into water	0.0039	0.0041	0.95
Ionizing radiation	Bqeq C-14 into air	0.039	0.036	1.09