Mirror Mirror on the wall, who is the greenest cup of all?

A Life Cycle Assessment of 10 Ounce Disposable Beverage Containers

ENVR E-151 Life Cycle and Supply Chain Assessment

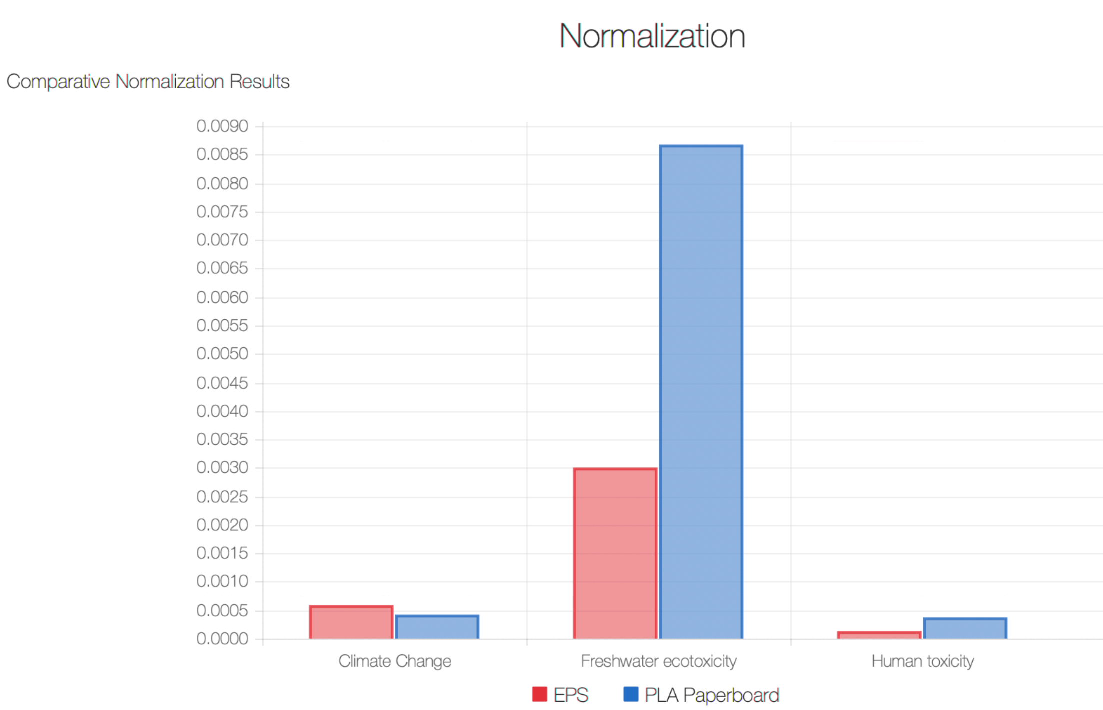
David Komet

Abstract

The objective of this Life Cycle Assessment (LCA) is to help inform the supply purchasing decisions of a large community foundation, and to leverage this research further to impact the supply purchasing decisions of the wider nonprofit community in San Antonio, Texas. This LCA will focus on an assessment of the environmental footprint of two different disposable beverage container options to determine which option has the lowest environmental footprint. The "Business-as-Usual Scenario" choice for the LCA is the ubiquitous 10 ounce expanded polystyrene (EPS) disposable beverage cup. The community foundation has already made adjustments to its purchasing decisions based on a recently adopted corporate sustainability policy, with the previously purchased EPS cups being replaced by a cup believed to be more in alignment with the new policy. The alternative, "greener," product is a 10 ounce polylactide (PLA) coated liquid paperboard cup sold under the brand name ecotainer®. The LCA uses the material weight of the 10 ounce containers consumed over 12 months as its functional unit and uses a cradle-to-gate approach. The cradle-to-gate approach was adopted as research indicates that the majority of environmental impacts for both material options occurs during the manufacturing of the cup material itself (Franklin 2011). All elements of the associated beverage production processes are excluded from the scope with the focus being solely on the functional unit of the number of 10 ounce cups used on an annual basis.

The LCA follows the ReCiPe Midpoint (I) impact assessment methodology and uses the World ReCiPe I/A (person/year) normalization and weighting set. The LCA also uses the World ReCiPe

(H) normalization and weighting set adjusted to my personal normalization factors. These adjustments were calculated on the basis of the results of the Cool California calculator to assess and quantify handprint requirements. The decision to stop purchasing EPS cups and switch to ecotainer® paper cups was made by staff under the assumption that a paper product would have a lower environmental impact than the EPS cups. This was also in alignment with a sustainability policy bias towards products that are compostable and away from material choices that are non-renewable. This original hypothesis, that EPS cups have a greater environmental impact, turns out to be true if the focus is solely on climate change. However, it is not true if the focus is on ecosystem (freshwater ecotoxicity) and human health impacts. This classic "it depends" dilemma requires the foundation and other nonprofits to decide which impact categories are most in alignment with their mission and to inform their decisions accordingly.



I. Goal and Scope

Background

Larger nonprofits, like community foundations, tend to host a lot of meetings and other community events given their relatively large boards and numerous standing committees (Price & Price 2019). When a large foundation also provides support services to the local nonprofit ecosystem, the number of meetings in any given period is significantly amplified. As an example, the San Antonio Area Foundation (SAAFDN) hosts, on average, 30-40 nonprofit training sessions and other meetings per month in addition to a very active board and committee meeting schedule. Approximately 600 area nonprofits are served by the SAAFDN with over 23,000 people attending events at SAAFDN facilities on an annual basis. And what's a meeting without liquid refreshment? With beverage consumption at events comes the need for a vessel of some kind from which to consume it.

At one of these recent community events, participant comments were made about the known toxicity issues with the expanded polystyrene (EPS) cups the SAAFDN provided for beverage consumption and involved an inquiry as to why the SAAFDN would make such an "obviously" negative human health purchasing decision. I was present when the comments were made and they got my attention both as a SAAFDN board member and as a sustainability professional. Reflecting back on the event, I noted that the SAAFDN lacked a corporate sustainability policy to even address the concerns. I felt this was an important policy for a community leader like the SAAFDN to adopt as a thought leader and trainer in nonprofit best practices. This led to a coordinated effort with Foundation staff to develop a first generation sustainability policy that was subsequently adopted by the SAAFDN board. I have provided this sustainability policy in the Appendix. Working on the policy generated not only an increased awareness about sustainability within the SAAFDN staff, it also led to immediate exploration by foundation staff to into opportunities for improving the environmental impact of the materials chosen in their operational supply chain. Once the policy was adopted, foundation staff began to implement material substitutions starting with a switch from purchasing disposable beverage cups made from expanded polystyrene cups (EPS) to an alternative polylactide (PLA) coated liquid paperboard cup marketed under the brand name ecotainer®. This decision was made under the belief that the ecotainer® product was the more environmentally responsible product choice, that it and conformed more closely with the sustainability policy. The policy change on cup purchases made to support meetings and events represented an easy, and publicly meaningful, step towards environmental responsibility. I would count myself as one of those community members who was pleased to see the change.

The Business-as-Usual Scenario (BAU) selected for this LCA is the number of 10 ounce expanded polystyrene (EPS) disposable beverage cups purchased and consumed over the period of one year. This is a relatively generic consumer good made out of a material also known by the brand name of STYROFOAM®™. EPS is a very light weight material derived from fossil fuels and is comprised of approximately 98% air. This renders the material very light weight, impact resistant and highly insulative given its low thermal conductivity. It is very popular and widely used across numerous industries including consumer packaged goods and building construction.

As a landfill material, EPS does not account for much weight of waste, but it does account for up to 30% of average landfill volume given its extensive use and its high volume to weight ratio. (Omnexus Website) With all of its benefits, the environmental impact concerns about EPS have centered around its fossil fuel basis, contributions to greenhouse gas emissions during manufacturing, human toxicity of component materials, and it's very long decomposition time horizon. Many concerned with sustainability best practices, including me, feel that using EPS material and containers of any kind does not represent an environmentally responsible choice and one we would like to avoid.

The Ecotainer product substitution for the EPS beverage cups on the other hand looks, feels and instinctively resonates as the more environmentally responsible product choice. Indeed, the manufacturer's write up on the product leaves even me feeling warm and fuzzy:
"International Paper's ecotainer® packaging products are sourced from fully renewable resources and made entirely in the USA. The fiber comes from responsibly managed forests through a procurement system that meets Sustainable Forestry Initiative® (SFI®) Chain of Custody standards, while the cup coating and lids use Ingeo™ biopolymer, a naturally advanced plant based material. This combination makes ecotainer® a fully compostable package in commercial composting facilities, which can reduce the amount of waste going to landfills." (International Paper website) The Ingeo™ biopolymer referred to in the product description is the PLA, or polylactic acid, liner of the ecotainer® that is cited as part of what makes the product"greener." According to the manufacturer, this biopolymer is derived from corn, cassava, sugar cane or beets (Naure Works). PLA is referred to in the ecoinvent 2.2.1

database as polylactide granules. As the LCA will demonstrate, the PLA associated with the ecotainer® is, in fact, a major contributor to the environmental impacts of the product.

My understanding of the LCA process prepares me for an outcome that I might find surprising as I undertake a comparative study of the two disposable containers, and will likely lead to the inevitable "it depends on priorities" when assessing which is the more environmentally sustainable option. My primary goal then with the LCA, is to undertake the study within the context of the SAFFDN's priorities as a community foundation, and to further communicate the LCA results to the wider nonprofit community through the SAAFDN. The hope is that this study will positively influence the purchasing behavior of other nonprofit organizations as well as the individuals who comprise this community by clearly illustrating the impacts of these two specific product choices, and by demonstrating the thought process as it relates to materials purchasing decisions in general. Ultimately, the goal is to maximize the handprint effect of switching from BAU to the alternative in alignment with the SAAFDN priorities.

Functional Unit

The primary function of a beverage cup is, rather obviously, to allow a person to hold liquid for subsequent consumption. To fulfill this function, SAAFDN staff historically ordered an average of 1,000 cups per month of 10 ounce disposable expanded polystyrene (EPS) beverage cups, or 12,000 cups per year. The LCA therefore uses 12,000 10 ounce disposable beverage cups over a period of one year as its functional unit. Equivalency between the BAU and the alternative ecotainer® cup is assumed given their similar size and functionality but does not take into consideration other performance aspects of a cup such as insulation values and durability.

Table 1: Products Modeled

10 oz. cups	grams/item	Number Functional Unit	Kg Total Functional Unit
EPS	2.9375 *	12,000	35.25
PLA-coated Paperboard	7.9375 *	12,000	95.25
* Average weight cup from Franklin 2011			

System Boundary

The LCA uses a "Cradle-to-Gate" approach. This system boundary was chosen as research has demonstrated that the majority of the environmental impacts of both container types occur during the material production phase of the product life cycle (Franklin 2011.)The LCA, therefore, will cover the following unit processes: (1) the production of expanded polystyrene (EPS) material, the base material for EPS cups, and (2) the production of polylactide (PLA) coated liquid packaging board, the base material for the alternative to BAU.

Impact Assessment Methodology

The LCA adopts the ReCiPe Midpoint (I) impact assessment methodology. Mid-point indicators are most appropriate for this LCA given the Cradle-to-Gate approach. The LCA uses the World ReCiPe I normalization and weighting set. The LCA also considers my personal normalization factors calculated on the basis of my personal results of the Cool California calculator to help quantify handprint requirements for offsetting my own footprint. These factors were used to modify the World ReCiPe (H) normalization and weighting set in OpenLCA.

Assumptions and Limitations

The production of both EPS and liquid paperboard are well known and large scale industrial processes undertaken by large corporate enterprises. The LCA therefore assumes that the production of both of these materials is generic and consistent in its supply chain requirements irrespective of where it is produced. It is also assumes that the performance characteristics of both products as a beverage container is comparable.

II. Data and Methodology

Personal Normalization Factors

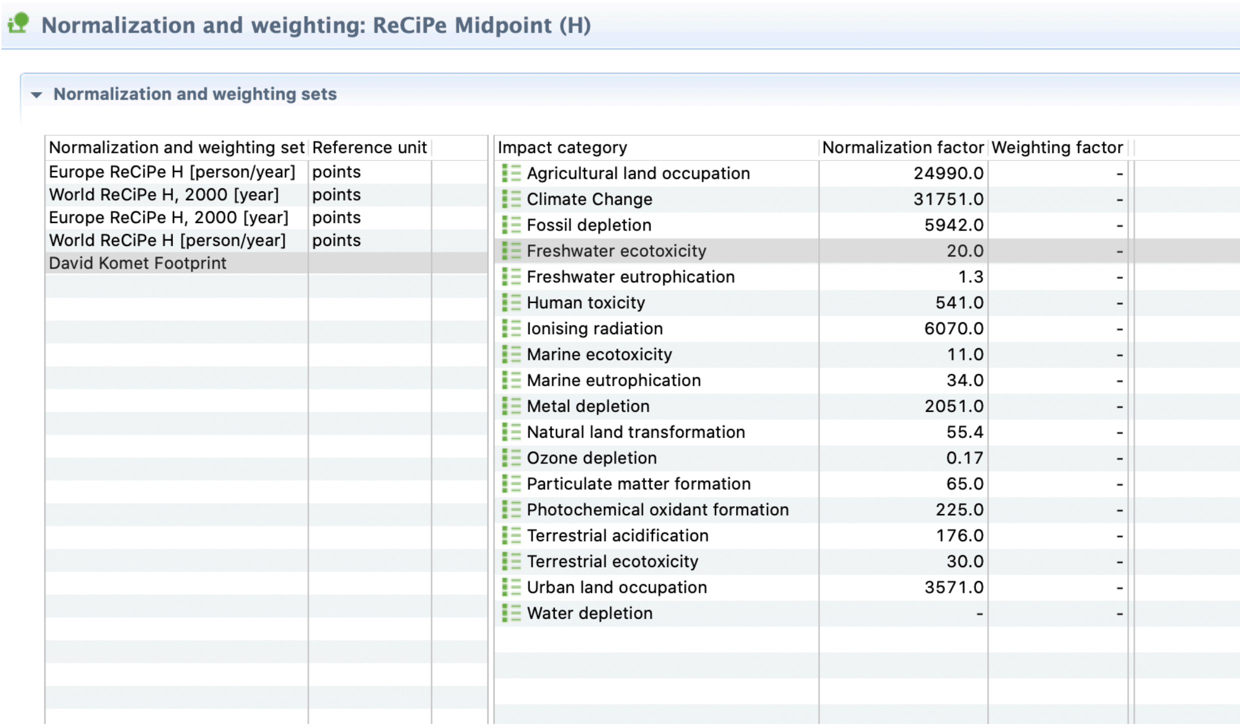
The table below reflects the personal normalization factors that resulted from running the Cool California calculator for households and individuals to assess my own environmental footprint. My calculator results showed an annual 31,751 kg CO2 eq impact. Using that as a basis of comparison to the US average of 24,000 kg CO2 eq, the same ratio of my footprint to the US per capita average for CO2 emissions was applied to all World ReCiPe (H) impact categories. The normalization factors were subsequently used to calculate the handprint requirements later in this report.

Table 2: Cool California Calculator results

Impact Category	**Calculated Normalization Factors**	**Units**	**US avg per person per yr**
	(impacts of me/year)		(TRACI 2.1: 2008 US per capita)
Human Health - carcinogens	6.68E-05	CTUh	5.05E-05
Acidification	120	kg SO2 eq	91
Eutrophication	29	kg N eq	22
Resource depletion - ff	22490	MJ surplus	17000
Human Health - non-carcinogens	0.001372	CTUh	0.001037
Ecotoxicity	14653	CTUe	11076
Ozone Depletion	0.21	kg CFC-11 eq	0.16
Global Warming	31751	kg CO2 eq	24000
Photochemical ozone formation	1852	kg O3 eq	1400
Respiratory effects	32	kg PM2.5 eq	24

In order to assess the handprint requirements of choosing one of the two scenarios for disposable beverage cups, the above calculated values were entered into a new “Normalization and Weighting Set” in the OpenLCA software. This gives the LCA a reference system for normalization that is specific to me and offsetting my environmental impact as it relates to the impacts of either disposable beverage cup option.

OpenLCA World ReCiPe (H) Results



Normalization and weighting: ReCiPe Midpoint (H)

Normalization and weighting sets

Normalization and weighting set	Reference unit
Europe ReCiPe H [person/year]	points
World ReCiPe H, 2000 [year]	points
Europe ReCiPe H, 2000 [year]	points
World ReCiPe H [person/year]	points
David Komet Footprint	

Impact category	Normalization factor	Weighting factor
Agricultural land occupation	24990.0	-
Climate Change	31751.0	-
Fossil depletion	5942.0	-
Freshwater ecotoxicity	20.0	-
Freshwater eutrophication	1.3	-
Human toxicity	541.0	-
Ionising radiation	6070.0	-
Marine ecotoxicity	11.0	-
Marine eutrophication	34.0	-
Metal depletion	2051.0	-
Natural land transformation	55.4	-
Ozone depletion	0.17	-
Particulate matter formation	65.0	-
Photochemical oxidant formation	225.0	-
Terrestrial acidification	176.0	-
Terrestrial ecotoxicity	30.0	-
Urban land occupation	3571.0	-
Water depletion	-	-

Foreground Data

Tables 3 and 4 below contain the foreground data for both BAU scenario and the alternative scenario. The LCA will not consider the background data related to transportation and grid variances depending on manufacturing location.

Table 3: BAU Scenario

Output	***Unit***	***Amount***	***Data Source***
1 EPS cup, 10 ounce	Grams	2.9375	Franklin 2011

Table 4: Alternative Scenario

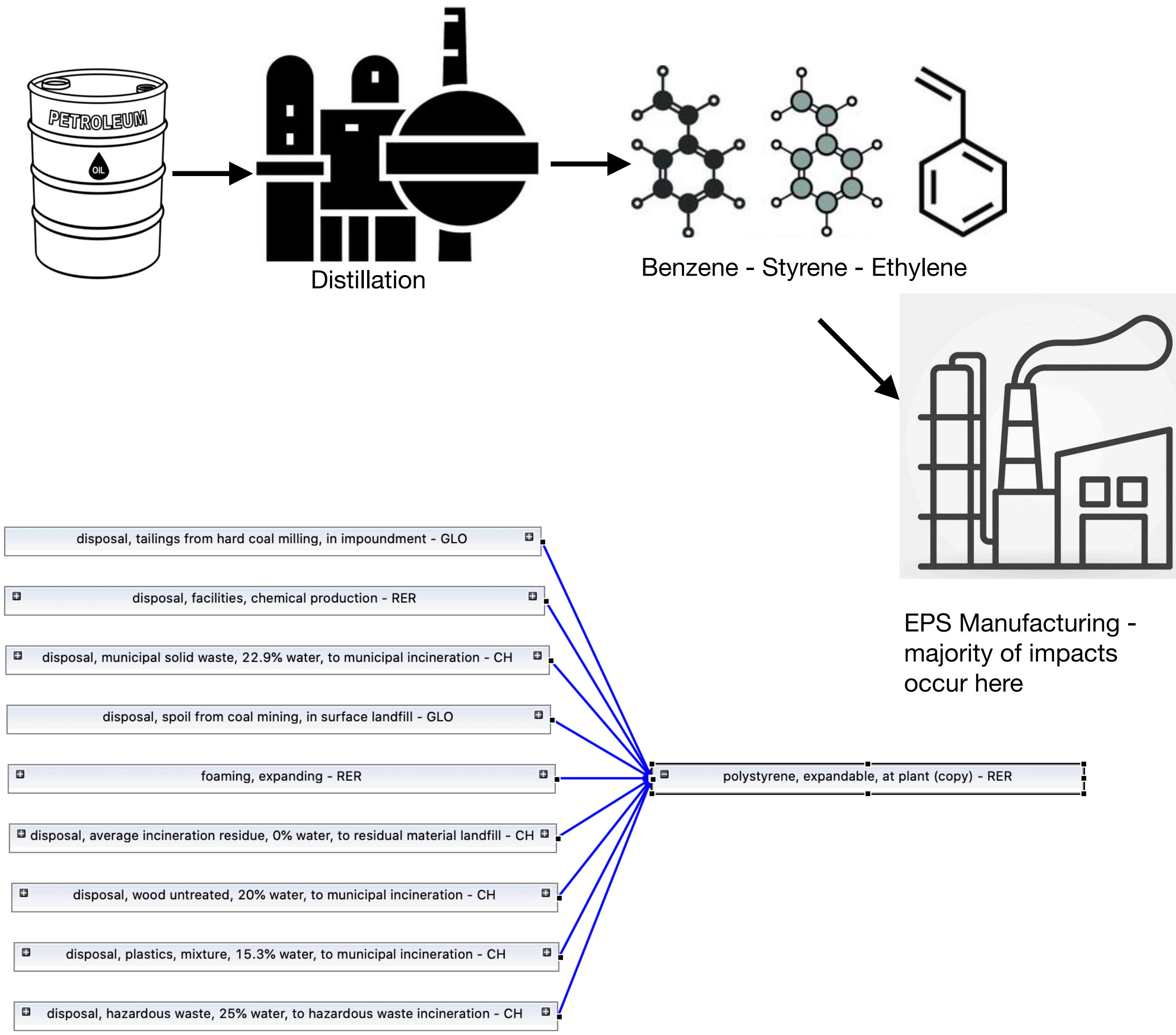
Output	***Unit***	***Amount***	***Data Source***
1 PLA paperboard cup	Grams	7.9375	Franklin 2011

Matching Foreground Data to Ecoinvent Process Data

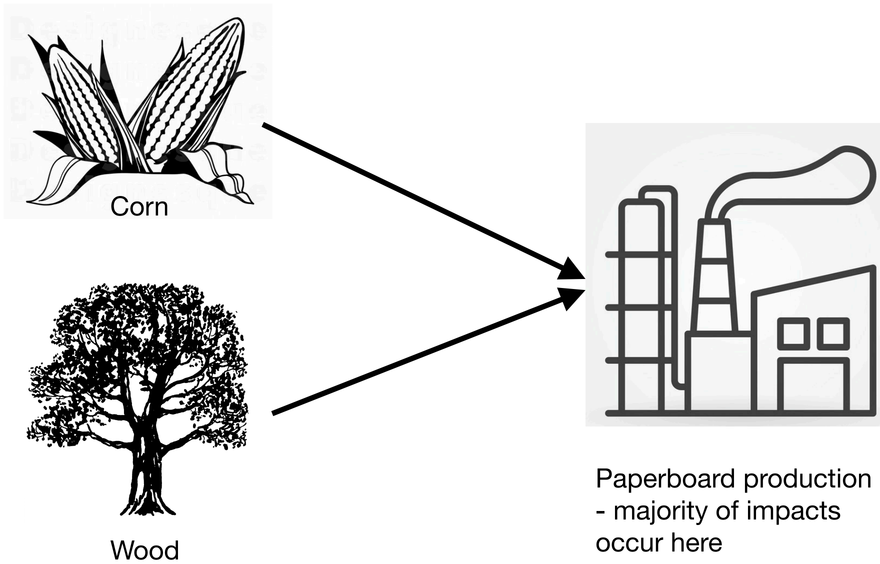
Tables matching foreground data to Ecoinvent process data are found in the Appendix. Input and output data for BAU and the Alternative scenario are presented.

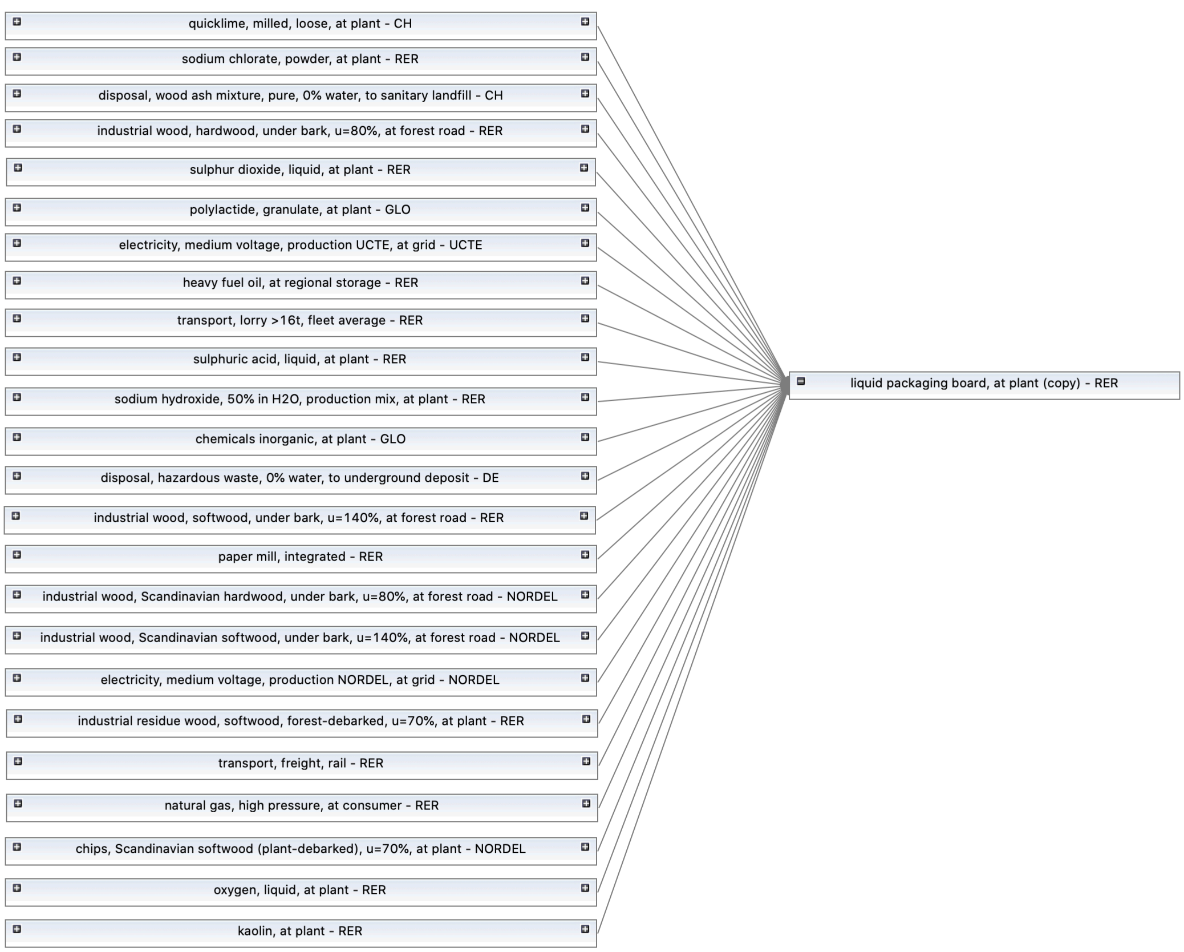
Supply chain flow diagram with labels

EPS Supply Chain



PLA - Coated Paperboard Supply Chain





Unit OpenLCA Process Screenshots

OpenLCA unit process screenshots for both the BAU and the Alternative Product System can be found in the Appendix.

III. Results and Interpretation

BAU vs Alternative Contribution Tree

Contribution tree screenshots from OpenLCA for the BAU and Alternative Product scenarios are presented in the Appendix and are organized by impact categories. Table 5 and Table 6 below reflect the relative contributions that key components of the product systems make to the primary impact categories being considered. In the BAU product system, we see that the foaming process converting polystyrene to expanded polystyrene is the primary driver of the environmental impacts across the board. In the case of freshwater ecotoxicity, the foaming process accounts for 51.57% of the impact, and solid waste disposal and incineration combined account for 44.57%. Human toxicity impacts see an even higher contribution from the foaming process at 68.36%, with the next largest contributions coming from disposal and incineration processes at 8.72%. And climate change impacts also see the largest contribution coming from the foaming process at 13.35%, with the disposal and incineration process accounting for .34%. All other contribution factors were below the cutoff point for this LCA.

Table 5: BAU - EPS Disposable Cups

Input	Ecosystems Fresh Water Ecotoxicity	Human Toxicity	Climate Change
Foaming, expanding	51.57%	68.36%	13.35%
Disposal, municipal solid waste, 22.9% to water, to municipal incineration	30.05%	1.24%	0.24%
Disposal, average incineration residue, 0% water, to residual material landfill	14.52%	7.48%	0.1%

With the alternative product system the contributions to all impact categories are dominated by the PLA used to coat the paperboard, with freshwater toxicity at 76.27%, human toxicity at 56.40% and climate change at 83.96%. Disposal to landfill has a 12.52% contribution to freshwater ecotoxicity and relatively small contributions to human toxicity and climate change at 5.47% and .03%. The energy consumption profile also makes a relatively small contribution in all categories with 1.63%, 2.47% and 3.52% respectively.

Table 6: Alternative - PLA Coated Paperboard

Input	Ecosystems Fresh Water Ecotoxicity	Human Toxicity	Climate Change
Polylactide, granulate at plant	76.27%	56.4%	83.96%
Disposal, wood ash mixture, pure, 0% water, to sanitary landfill	12.52%	5.47%	0.03%
Electricity, medium voltage, production NORDEL, at grid	1.63%	2.47%	3.52%

BAU vs Alternative Normalization and Weighting - Stand Alone Results

The stand-alone normalization and weighting screenshots from OpenLCA are presented in the Appendix. The results of the normalization and weighting analysis shows that the highest leverage potential for both product systems exists with the fresh water ecotoxicity and climate change impact categories. The human toxicity impact category offers the lowest leverage potential.

Table 7: BAU - EPS Disposable Cups

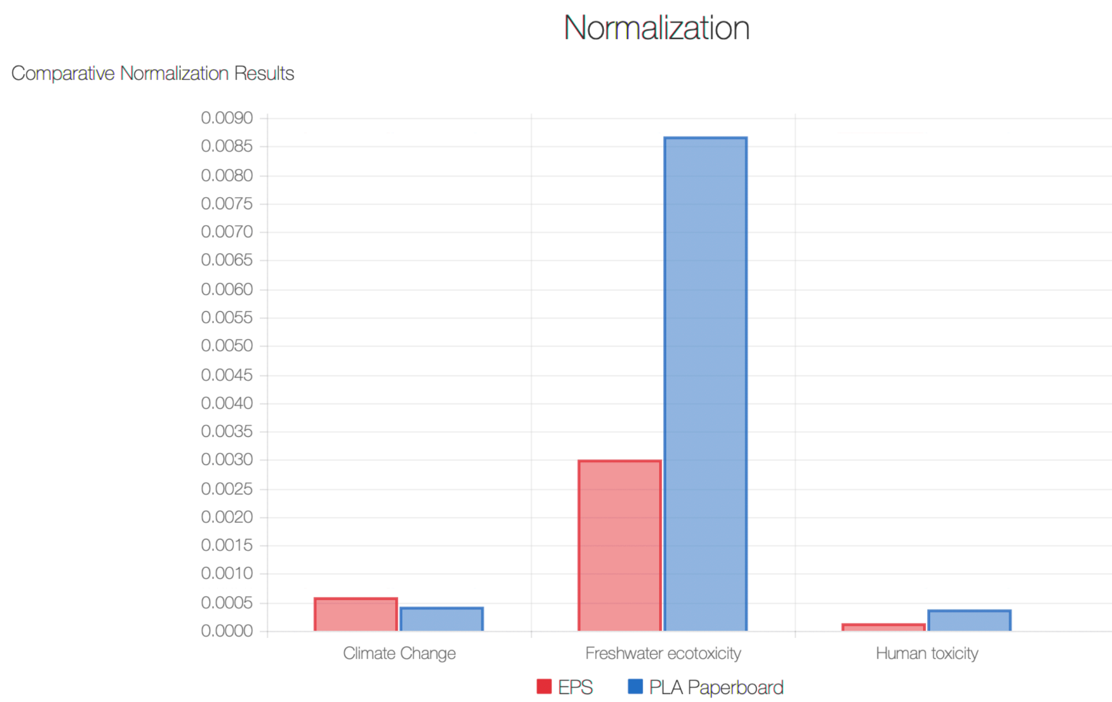
Leverage	**Ecosystems** Fresh Water Ecotoxicity	**Human Toxicity**	**Climate Change**
High	X		X
Low		X	

Table 8: Alternative - PLA Coated Paperboard

Leverage	**Ecosystems** Fresh Water Ecotoxicity	**Human Toxicity**	**Climate Change**
High	X		X
Low		X	

BAU vs Alternative Normalization and Weighting - Comparative Results

The normalization graph below illustrates that PLA paperboard has a worse environmental performance relative to EPS in two of the impact categories with the highest leverage potential. This is particularly dramatic when considering freshwater ecotoxicity impacts. PLA paperboard does outperform EPS when it comes to climate change impacts.

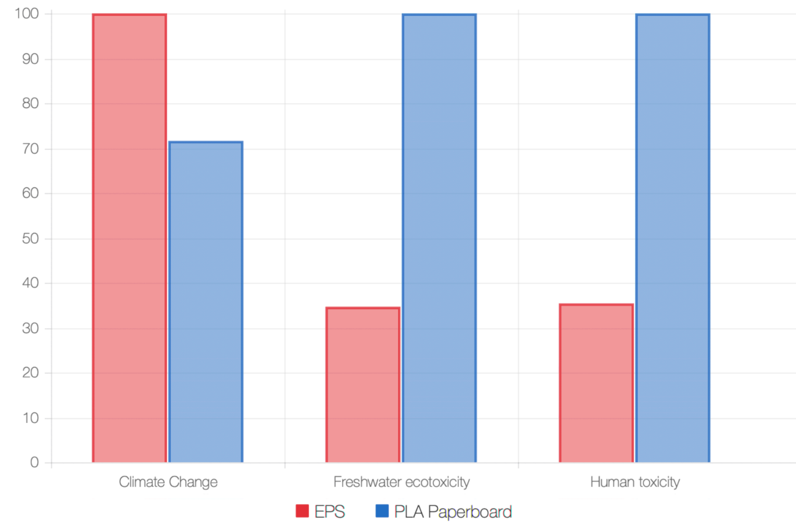


IV. Conclusions

The original hypothesis and assumptions made by SAAFDN staff in choosing to switch from using EPS disposable beverage cups to PLA coated paperboard cups proved to be correct when taken into context with the priorities of the foundation. Interviews conducted with SAAFDN leadership where the LCA results were discussed reaffirmed their core belief that climate change was the global driver of community health and therefore the appropriate impact category against which to weigh material and product options. It was, however a surprise to many, including me, to see the relatively dramatic results to the contrary when considering ecosystem impact categories, like freshwater eco toxicity, and human health impact categories like human toxicity.

Relative Results

The following chart shows the relative indicator results of the respective project variants. For each indicator, the maximum result is set to 100% and the results of the other variants are displayed in relation to this result.



Sensitivity analysis to shift these dynamics could consider alternative grid scenarios, the purchase of renewable credits by manufacturers and improvements in farming practices in the case of the alternative. My hand printing effort to influence the behavior of the SAAFDN and other community members to make the same alternative material choice would suggest substantial scale in order to bring me to net positive. Specifically, switching 6,792,000 EPS disposable beverage cups to the PLA coated liquid paperboard alternative would be required to offset my annual climate change footprint as calculated by the Cool California Calculator. While that number at first glance seems unachievable, I considered the following strategies as worthy of pursuing to try and achieve that:

- Disseminate LCA outcomes to the 600 nonprofits in the SAAFDN orbit; assume 1,000 cups each per year per nonprofit = 600,000 cups
- Publish information on SAAFDN website = unknown

- Influence 23,000 people per year attending SAAFDN events; assume 1 cup per month = 276,000 cups
- Influence each of the 23,000 people to influence another 5 people = 1,380,000
- The SAAFDN owns a large local movie theater chain; influence the theater chain purchasing habits and follow on communication opportunity with movie patrons; assume 1 cup per patron = 5,600,000
- Total potential influence: 7,856,000 cups

The total achievable hand print is truly unknown, but I believe the strategies presented are real opportunities. A compliment to those efforts is to reflect on my own personal travel habits, particularly air travel, where my footprint is the heaviest and the greatest opportunity for climate change impact reductions exist. While the LCA results support the material choices made by the SAAFDN, the truth is neither scenario is ideal. The ultimate goal is to replace the disposable cup habit altogether with washable, durable cups suitable for both hot and cold beverages, and to cultivate a BYOC (bring your own cup) community habit. LCA research has shown that a reusable ceramic mug has lower environmental impacts than EPS cups as long as it is used at least 46 times, with a stainless steel mug requiring at least 396 uses. (Paster 2006)

Table 9: Handprint Requirement

Impact Category	10 oz EPS Cups	10 oz Ecotainer	Difference	Functional Unit	Total Annual Offset	Personal Footprint	Handprint Requirement
	kg CO2 eq	kg CO2 eq	kg CO2 eq	kg	kg CO2 eq	kg CO2 eq	Cups switched
Climate Change	5.60	4.01	1.59	35.25	56.05	31,751	6,792,000

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VI. Appendix

San Antonio Area Foundation Corporate Sustainability Policy

San Antonio Area Foundation
Where Giving and Community Connect

Environmental Sustainability Policy

Human Resources 209.1

Staff Owner (Title):	Vice President, Human Resources	Approved Date: 9/24/19
Approved By:	Board of Directors	Review Cycle:
Resp. Committee:	Board of Directors	

1. Purpose

The Area Foundation will encourage staff, volunteers, vendors, visitors, and other Area Foundation stakeholders to minimize their impact on the environment by developing and implementing effective green practices and procedures in its daily operations.

2. Definitions

- **Biodegradable Products Institute (BPI) Certified**: Items that biodegrade at a rate comparable to yard trimmings, food scraps, and other compostable materials.
- **Bisphenol A (BPA) Free**: does not use the organic compound Bisphenol A in its construction in plastic containers, cans, and other materials that contain food or drink.
- **Compostable**: a product that can disintegrate into natural elements in a compost environment and leaves no toxicity in the soil.
- **Environmental Sustainability**: Environmental resources such as renewable energy that protect and maintain the environment for future generations.
- **Eco-friendly:** not harmful to the environment.
- **Life-Cycle Assessment:** a technique used to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair, and maintenance, and disposal or recycling.
- **Recycle**: convert waste into reusable material.

3. Sustainable Practices

The San Antonio Area Foundation will minimize its impact on the environment by:

- having an environmental sustainability awareness culture;
- reusing and recycling office products and other materials;

- using compostable and recyclable materials (cups, plates, utensils, copy paper, etc.) that are BPI certified and BPA free and may be made from plants and other natural materials unless life-cycle assessments on materials indicate lower environmental impacts from petroleum-based products.;
- ensuring the responsible use of energy throughout the organization with motion sensors and other low energy products;
- conducting regular audits, evaluations, and self-assessments of this policy; and
- working with vendors who use sustainable environment practices.

4. Responsibility

The San Antonio Area Foundation's Human Resources Department will introduce the new policy and procedures to staff through its all staff meetings and in the employee handbook. Other stakeholders including volunteers, vendors, supporting organizations, and visitors will receive information on this policy and procedures.

BAU Product System Ecoinvent Process Data

BAU Scenario Inputs				
Flow	**Category**	**Flow property**	**Unit**	**Amount**
Aluminium, 24% in bauxite, 11% in crude ore, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.00017511
Anhydrite, in ground	Elementary flows/ Resource/in ground	Mass	kg	8.4227E-06
Barite, 15% in crude ore, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.000001291
Calcium carbonate, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.00038791
Chromium, 25.5% in chromite, 11.6% in crude ore, in ground	Elementary flows/ Resource/in ground	Mass	kg	2.3342E-08
Cinnabar, in ground	Elementary flows/ Resource/in ground	Mass	kg	8.9792E-09
Clay, bentonite, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.000082878
Clay, unspecified, in ground	Elementary flows/ Resource/in ground	Mass	kg	1.1538E-07
Coal, brown, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.000030897
Coal, hard, unspecified, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.1463
Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.00018906
disposal, average incineration residue, 0% water, to residual material landfill	waste management/ residual material landfill	Mass	kg	0.015489
disposal, facilities, chemical production	waste management/ building demolition	Mass	kg	0.00011133
disposal, hazardous waste, 25% water, to hazardous waste incineration	waste management/ hazardous waste incineration	Mass	kg	0.011966
disposal, municipal solid waste, 22.9% water, to municipal incineration	waste management/ municipal incineration	Mass	kg	0.02695
disposal, plastics, mixture, 15.3% water, to municipal incineration	waste management/ municipal incineration	Mass	kg	0.0018953
disposal, spoil from coal mining, in surface landfill	waste management/ others	Mass	kg	0.045549
disposal, tailings from hard coal milling, in impoundment	waste management/ others	Mass	kg	0.0078784

disposal, wood untreated, 20% water, to municipal incineration	waste management/ municipal incineration	Mass	kg	0.0001192
Dolomite, in ground	Elementary flows/ Resource/in ground	Mass	kg	4.2649E-06
Energy, gross calorific value, in biomass	Elementary flows/ Resource/biotic	Energy	MJ	0.19339
Energy, potential (in hydropower reservoir), converted	Elementary flows/ Resource/in water	Energy	MJ	0.22674
Feldspar, in ground	Elementary flows/ Resource/in ground	Mass	kg	2.7333E-16
Fluorspar, 92%, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.000014954
foaming, expanding	plastics/processing	Mass	kg	1
Gas, natural, in ground	Elementary flows/ Resource/in ground	Volume	m3	0.90765
Granite, in ground	Elementary flows/ Resource/in ground	Mass	kg	4.9393E-13
Gravel, in ground	Elementary flows/ Resource/in ground	Mass	kg	1.2817E-06
Iron, 46% in ore, 25% in crude ore, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.00034742
Lead, 5.0% in sulfide, Pb 3.0%, Zn, Ag, Cd, In, in ground	Elementary flows/ Resource/in ground	Mass	kg	5.6215E-07
Magnesite, 60% in crude ore, in ground	Elementary flows/ Resource/in ground	Mass	kg	2.4497E-10
Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground	Elementary flows/ Resource/in ground	Mass	kg	4.4825E-07
Nickel, 1.98% in silicates, 1.04% in crude ore, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.000027335
Oil, crude, in ground	Elementary flows/ Resource/in ground	Mass	kg	1.0429
Olivine, in ground	Elementary flows/ Resource/in ground	Mass	kg	3.2595E-06
Peat, in ground	Elementary flows/ Resource/biotic	Mass	kg	0.0008526
Phosphorus, 18% in apatite, 12% in crude ore, in ground	Elementary flows/ Resource/in ground	Mass	kg	1.5563E-11
Sand, unspecified, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.00056409
Shale, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.000023845
Sodium chloride, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.0022702
Sodium nitrate, in ground	Elementary flows/ Resource/in ground	Mass	kg	7.3492E-10
Sulfur, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.0001978
Sylvite, 25 % in sylvinite, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.000006424
Talc, in ground	Elementary flows/ Resource/in ground	Mass	kg	1.2998E-31

TiO2, 95% in rutile, 0.40% in crude ore, in ground	Elementary flows/ Resource/in ground	Mass	kg	7.7123E-31
Uranium, in ground	Elementary flows/ Resource/in ground	Mass	kg	6.5403E-06
Water, cooling, unspecified natural origin	Elementary flows/ Resource/in water	Volume	m3	0.16509
Water, river	Elementary flows/ Resource/in water	Volume	m3	0.00066807
Water, salt, ocean	Elementary flows/ Resource/in water	Volume	m3	0.00051993
Water, unspecified natural origin	Elementary flows/ Resource/in water	Volume	m3	0.0047283
Water, well, in ground	Elementary flows/ Resource/in water	Volume	m3	2.7848E-10
Wood, unspecified, standing	Elementary flows/ Resource/biotic	Volume	m3	8.2721E-08
Zinc, 9.0% in sulfide, Zn 5.3%, Pb, Ag, Cd, In, in ground	Elementary flows/ Resource/in ground	Mass	kg	0.00002573

BAU Scenario Outputs				
Flow	**Category**	**Flow property**	**Unit**	**Amount**
Acidity, unspecified	Elementary flows/ Emission to water/ river	Mass	kg	7.8209E-06
Aldehydes, unspecified	Elementary flows/ Emission to air/high population density	Mass	kg	1.0805E-13
Aluminium	Elementary flows/ Emission to water/ river	Mass	kg	1.1746E-06
Ammonia	Elementary flows/ Emission to air/high population density	Mass	kg	7.3479E-09
Ammonium, ion	Elementary flows/ Emission to water/ river	Mass	kg	0.000029316
Antimony	Elementary flows/ Emission to air/high population density	Mass	kg	3.3341E-11
AOX, Adsorbable Organic Halogen as Cl	Elementary flows/ Emission to water/ river	Mass	kg	6.045E-08
Arsenic	Elementary flows/ Emission to air/high population density	Mass	kg	1.0231E-08
Arsenic, ion	Elementary flows/ Emission to water/ river	Mass	kg	8.2869E-10
Benzene	Elementary flows/ Emission to water/ river	Mass	kg	1.6272E-06
Benzene	Elementary flows/ Emission to air/high population density	Mass	kg	0.000018257

Benzene, ethyl-	Elementary flows/ Emission to air/high population density	Mass	kg	5.3046E-06
BOD5, Biological Oxygen Demand	Elementary flows/ Emission to water/ river	Mass	kg	0.00026869
Bromate	Elementary flows/ Emission to water/ river	Mass	kg	3.2808E-09
Cadmium	Elementary flows/ Emission to air/high population density	Mass	kg	1.1562E-09
Cadmium, ion	Elementary flows/ Emission to water/ river	Mass	kg	2.9165E-11
Calcium, ion	Elementary flows/ Emission to water/ river	Mass	kg	0.00001633
Carbon dioxide, biogenic	Elementary flows/ Emission to air/high population density	Mass	kg	0.0050858
Carbon dioxide, fossil	Elementary flows/ Emission to air/high population density	Mass	kg	2.5405
Carbon disulfide	Elementary flows/ Emission to air/high population density	Mass	kg	4.2459E-09
Carbon monoxide, biogenic	Elementary flows/ Emission to air/high population density	Mass	kg	7.5435E-06
Carbon monoxide, fossil	Elementary flows/ Emission to air/high population density	Mass	kg	0.0037682
Carbonate	Elementary flows/ Emission to water/ river	Mass	kg	0.00011484
Chlorate	Elementary flows/ Emission to water/ river	Mass	kg	6.0931E-07
Chloride	Elementary flows/ Emission to water/ river	Mass	kg	0.00056535
Chlorinated solvents, unspecified	Elementary flows/ Emission to water/ river	Mass	kg	3.3553E-08
Chlorine	Elementary flows/ Emission to water/ river	Mass	kg	2.1365E-08
Chlorine	Elementary flows/ Emission to air/high population density	Mass	kg	9.8195E-07
Chromium	Elementary flows/ Emission to air/high population density	Mass	kg	2.8319E-06
Chromium, ion	Elementary flows/ Emission to water/ river	Mass	kg	8.7064E-12
COD, Chemical Oxygen Demand	Elementary flows/ Emission to water/ river	Mass	kg	0.0019158

Copper	Elementary flows/ Emission to air/high population density	Mass	kg	6.8708E-08
Copper, ion	Elementary flows/ Emission to water/ river	Mass	kg	1.8509E-07
Cyanide	Elementary flows/ Emission to water/ river	Mass	kg	3.293E-11
Cyanide	Elementary flows/ Emission to air/high population density	Mass	kg	2.1719E-18
Dinitrogen monoxide	Elementary flows/ Emission to air/high population density	Mass	kg	2.145E-08
Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Elementary flows/ Emission to air/high population density	Mass	kg	1.0849E-40
Dissolved solids	Elementary flows/ Emission to water/ river	Mass	kg	0.0011785
Ethane, 1,2-dichloro-	Elementary flows/ Emission to water/ river	Mass	kg	2.4554E-11
Ethane, 1,2-dichloro-	Elementary flows/ Emission to air/high population density	Mass	kg	1.5705E-09
Ethene	Elementary flows/ Emission to air/high population density	Mass	kg	6.6613E-06
Ethene, chloro-	Elementary flows/ Emission to air/high population density	Mass	kg	7.5891E-10
Ethene, chloro-	Elementary flows/ Emission to water/ river	Mass	kg	1.7223E-11
Fluoride	Elementary flows/ Emission to water/ river	Mass	kg	3.7664E-07
Fluorine	Elementary flows/ Emission to air/high population density	Mass	kg	3.5878E-08
Heat, waste	Elementary flows/ Emission to air/high population density	Energy	MJ	42.383
Hydrocarbons, aliphatic, alkanes, cyclic	Elementary flows/ Emission to air/high population density	Mass	kg	5.5852E-06
Hydrocarbons, aromatic	Elementary flows/ Emission to air/high population density	Mass	kg	0.000028169
Hydrocarbons, chlorinated	Elementary flows/ Emission to air/high population density	Mass	kg	6.8211E-07
Hydrocarbons, unspecified	Elementary flows/ Emission to water/ river	Mass	kg	0.00016404
Hydrogen	Elementary flows/ Emission to air/high population density	Mass	kg	0.000060023

Hydrogen chloride	Elementary flows/ Emission to air/high population density	Mass	kg	0.000059488
Hydrogen fluoride	Elementary flows/ Emission to air/high population density	Mass	kg	2.1959E-06
Hydrogen sulfide	Elementary flows/ Emission to air/high population density	Mass	kg	1.193E-08
Iron, ion	Elementary flows/ Emission to water/ river	Mass	kg	4.3382E-08
Lead	Elementary flows/ Emission to air/high population density	Mass	kg	2.7527E-07
Lead	Elementary flows/ Emission to water/ river	Mass	kg	2.0484E-09
Magnesium	Elementary flows/ Emission to water/ river	Mass	kg	5.2183E-09
Manganese	Elementary flows/ Emission to water/ river	Mass	kg	2.6294E-10
Mercury	Elementary flows/ Emission to air/high population density	Mass	kg	1.8381E-09
Mercury	Elementary flows/ Emission to water/ river	Mass	kg	1.9539E-10
Methane, biogenic	Elementary flows/ Emission to air/high population density	Mass	kg	0.00006252
Methane, chlorodifluoro-, HCFC-22	Elementary flows/ Emission to air/high population density	Mass	kg	0.000001124
Methane, dichloro-, HCC-30	Elementary flows/ Emission to air/high population density	Mass	kg	3.0135E-09
Methane, fossil	Elementary flows/ Emission to air/high population density	Mass	kg	0.031231
Molybdenum	Elementary flows/ Emission to water/ river	Mass	kg	7.2409E-09
Nickel	Elementary flows/ Emission to air/high population density	Mass	kg	5.1484E-06
Nickel, ion	Elementary flows/ Emission to water/ river	Mass	kg	1.2942E-07
Nitrate	Elementary flows/ Emission to water/ river	Mass	kg	8.2685E-06
Nitrogen	Elementary flows/ Emission to water/ river	Mass	kg	3.1995E-06
Nitrogen oxides	Elementary flows/ Emission to air/high population density	Mass	kg	0.0048374

NMVOC, non-methane volatile organic compounds, unspecified origin	Elementary flows/ Emission to air/high population density	Mass	kg	0.00517
Oils, unspecified	Elementary flows/ Emission to water/ river	Mass	kg	0.000036982
Particulates, < 2.5 um	Elementary flows/ Emission to air/high population density	Mass	kg	0.00022166
Particulates, > 10 um	Elementary flows/ Emission to air/high population density	Mass	kg	0.00028373
Particulates, > 2.5 um, and < 10um	Elementary flows/ Emission to air/high population density	Mass	kg	0.00038126
Phenol	Elementary flows/ Emission to water/ river	Mass	kg	4.0967E-07
Phosphorus	Elementary flows/ Emission to water/ river	Mass	kg	0.0000629
polystyrene, expandable, at plant	plastics/polymers	Mass	kg	1
Potassium, ion	Elementary flows/ Emission to water/ river	Mass	kg	2.0317E-07
Propene	Elementary flows/ Emission to air/high population density	Mass	kg	0.000004934
Selenium	Elementary flows/ Emission to air/high population density	Mass	kg	3.5441E-11
Silicon	Elementary flows/ Emission to water/ river	Mass	kg	1.3601E-19
Silver	Elementary flows/ Emission to air/high population density	Mass	kg	1.0233E-09
Sodium, ion	Elementary flows/ Emission to water/ river	Mass	kg	0.00028051
Strontium	Elementary flows/ Emission to water/ river	Mass	kg	5.0474E-11
Styrene	Elementary flows/ Emission to air/high population density	Mass	kg	0.000045081
Sulfate	Elementary flows/ Emission to water/ river	Mass	kg	0.00040043
Sulfate	Elementary flows/ Emission to air/high population density	Mass	kg	7.5125E-15
Sulfide	Elementary flows/ Emission to water/ river	Mass	kg	1.8266E-07
Sulfite	Elementary flows/ Emission to water/ river	Mass	kg	6.3987E-09

Sulfur dioxide	Elementary flows/ Emission to air/high population density	Mass	kg	0.0070006
Suspended solids, unspecified	Elementary flows/ Emission to water/ river	Mass	kg	0.0017507
Tin, ion	Elementary flows/ Emission to water/ river	Mass	kg	4.3992E-14
TOC, Total Organic Carbon	Elementary flows/ Emission to water/ river	Mass	kg	0.000038165
Toluene	Elementary flows/ Emission to air/high population density	Mass	kg	0.000002536
Xylene	Elementary flows/ Emission to air/high population density	Mass	kg	1.0609E-06
Zinc	Elementary flows/ Emission to air/high population density	Mass	kg	3.2402E-08
Zinc, ion	Elementary flows/ Emission to water/ river	Mass	kg	3.7792E-08

Alternative Product System Ecoinvent Process Data

Alternative Scenario Inputs				
Flow	**Category**	**Flow property**	**Unit**	**Amount**
chemicals inorganic, at plant	chemicals/ inorganics	Mass	kg	0.012
chips, Scandinavian softwood (plant-debarked), u=70%, at plant	wooden materials/ extraction	Volume	m3	0.00022
disposal, hazardous waste, 0% water, to underground deposit	waste management/ underground deposit	Mass	kg	0.00013
disposal, wood ash mixture, pure, 0% water, to sanitary landfill	waste management/ sanitary landfill	Mass	kg	0.038
electricity, medium voltage, production NORDEL, at grid	electricity/ production mix	Energy	kWh	0.72
electricity, medium voltage, production UCTE, at grid	electricity/ production mix	Energy	kWh	0.18
heavy fuel oil, at regional storage	oil/fuels	Mass	kg	0.0364
industrial residue wood, softwood, forest-debarked, u=70%, at plant	wooden materials/ extraction	Volume	m3	0.000055
industrial wood, hardwood, under bark, u=80%, at forest road	wooden materials/ extraction	Volume	m3	0.000167

industrial wood, Scandinavian hardwood, under bark, u=80%, at forest road	wooden materials/ extraction	Volume	m3	0.000668
industrial wood, Scandinavian softwood, under bark, u=140%, at forest road	wooden materials/ extraction	Volume	m3	0.0013
industrial wood, softwood, under bark, u=140%, at forest road	wooden materials/ extraction	Volume	m3	0.000324
kaolin, at plant	chemicals/ inorganics	Mass	kg	0.067
natural gas, high pressure, at consumer	natural gas/fuels	Energy	MJ	0.781
oxygen, liquid, at plant	chemicals/ inorganics	Mass	kg	0.005
paper mill, integrated	paper & cardboard/ graphic paper	Number of items	Item(s)	5.44E-11
polylactide, granulate, at plant	plastics/ polymers	Mass	kg	1
quicklime, milled, loose, at plant	construction materials/ additives	Mass	kg	0.009
sodium chlorate, powder, at plant	chemicals/ inorganics	Mass	kg	0.0077
sodium hydroxide, 50% in H2O, production mix, at plant	chemicals/ inorganics	Mass	kg	0.0105
sulphur dioxide, liquid, at plant	chemicals/ inorganics	Mass	kg	0.0036
sulphuric acid, liquid, at plant	chemicals/ inorganics	Mass	kg	0.0077
transport, freight, rail	transport systems/train	Goods transport (mass*distance)	t*km	0.166
transport, lorry >16t, fleet average	transport systems/road	Goods transport (mass*distance)	t*km	0.298
Water, unspecified natural origin	Elementary flows/Resource/ in water	Volume	m3	0.0532

Alternative Scenario Outputs				
Flow	**Category**	**Flow property**	**Unit**	**Amount**
Acetaldehyde	Elementary flows/Emission to air/high population density	Mass	kg	0.000000566
Acetic acid	Elementary flows/Emission to air/high population density	Mass	kg	0.00000102

Acetone	Elementary flows/Emission to air/high population density	Mass	kg	0.000000225
Ammonia	Elementary flows/Emission to air/high population density	Mass	kg	0.00000967
AOX, Adsorbable Organic Halogen as Cl	Elementary flows/Emission to water/river	Mass	kg	0.0000459
Arsenic	Elementary flows/Emission to air/high population density	Mass	kg	2.51E-08
Benzene	Elementary flows/Emission to air/high population density	Mass	kg	0.00000539
Benzene, ethyl-	Elementary flows/Emission to air/high population density	Mass	kg	0.000000168
Benzene, hexachloro-	Elementary flows/Emission to air/high population density	Mass	kg	4.02E-14
Benzo(a)pyrene	Elementary flows/Emission to air/high population density	Mass	kg	2.84E-09
BOD5, Biological Oxygen Demand	Elementary flows/Emission to water/river	Mass	kg	0.00197
Bromine	Elementary flows/Emission to air/high population density	Mass	kg	0.000000335
Butane	Elementary flows/Emission to air/high population density	Mass	kg	0.000000547
Cadmium	Elementary flows/Emission to air/high population density	Mass	kg	5.34E-08
Calcium	Elementary flows/Emission to air/high population density	Mass	kg	0.0000328

Carbon dioxide, biogenic	Elementary flows/Emission to air/high population density	Mass	kg	0.53
Carbon dioxide, fossil	Elementary flows/Emission to air/high population density	Mass	kg	0.156
Carbon monoxide, biogenic	Elementary flows/Emission to air/high population density	Mass	kg	0.000268
Carbon monoxide, fossil	Elementary flows/Emission to air/high population density	Mass	kg	0.0000121
Chlorine	Elementary flows/Emission to air/high population density	Mass	kg	0.00000101
Chromium	Elementary flows/Emission to air/high population density	Mass	kg	4.58E-08
Chromium VI	Elementary flows/Emission to air/high population density	Mass	kg	4.63E-10
Cobalt	Elementary flows/Emission to air/high population density	Mass	kg	4.95E-08
COD, Chemical Oxygen Demand	Elementary flows/Emission to water/river	Mass	kg	0.0149
Copper	Elementary flows/Emission to air/high population density	Mass	kg	0.000000196
Dinitrogen monoxide	Elementary flows/Emission to air/high population density	Mass	kg	0.0000164
Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Elementary flows/Emission to air/high population density	Mass	kg	1.74E-13
Ethanol	Elementary flows/Emission to air/high population density	Mass	kg	0.00000045

Fluorine	Elementary flows/Emission to air/high population density	Mass	kg	0.000000279
Formaldehyde	Elementary flows/Emission to air/high population density	Mass	kg	0.00000148
Heat, waste	Elementary flows/Emission to air/high population density	Energy	MJ	11.8
Hydrocarbons, aliphatic, alkanes, unspecified	Elementary flows/Emission to air/high population density	Mass	kg	0.00000598
Hydrocarbons, aliphatic, unsaturated	Elementary flows/Emission to air/high population density	Mass	kg	0.0000174
Hydrocarbons, aromatic	Elementary flows/Emission to air/high population density	Mass	kg	0.000000225
Hydrogen chloride	Elementary flows/Emission to air/high population density	Mass	kg	0.00000216
Hydrogen fluoride	Elementary flows/Emission to air/high population density	Mass	kg	0.000000216
Hydrogen sulfide	Elementary flows/Emission to air/high population density	Mass	kg	0.00007
Iron	Elementary flows/Emission to air/high population density	Mass	kg	0.00000027
Lead	Elementary flows/Emission to air/high population density	Mass	kg	0.000000225
liquid packaging board, at plant	paper & cardboard/ cardboard & corrugated board	Mass	kg	1

m-Xylene	Elementary flows/Emission to air/high population density	Mass	kg	0.00000067
Magnesium	Elementary flows/Emission to air/high population density	Mass	kg	0.00000201
Manganese	Elementary flows/Emission to air/high population density	Mass	kg	0.000000949
Mercury	Elementary flows/Emission to air/high population density	Mass	kg	1.92E-09
Methane, biogenic	Elementary flows/Emission to air/high population density	Mass	kg	0.00000223
Methane, fossil	Elementary flows/Emission to air/high population density	Mass	kg	0.00000606
Methanol	Elementary flows/Emission to air/high population density	Mass	kg	0.000000765
Molybdenum	Elementary flows/Emission to air/high population density	Mass	kg	0.000000024
Nickel	Elementary flows/Emission to air/high population density	Mass	kg	0.00000101
Nitrogen	Elementary flows/Emission to water/river	Mass	kg	0.00018
Nitrogen oxides	Elementary flows/Emission to air/high population density	Mass	kg	0.00087
NMVOC, non-methane volatile organic compounds, unspecified origin	Elementary flows/Emission to air/high population density	Mass	kg	0.00000335
PAH, polycyclic aromatic hydrocarbons	Elementary flows/Emission to air/high population density	Mass	kg	7.07E-08

Particulates, < 2.5 um	Elementary flows/Emission to air/high population density	Mass	kg	0.0000737
Particulates, > 10 um	Elementary flows/Emission to air/high population density	Mass	kg	0.0000077
Particulates, > 2.5 um, and < 10um	Elementary flows/Emission to air/high population density	Mass	kg	0.0000086
Pentane	Elementary flows/Emission to air/high population density	Mass	kg	0.000000937
Phenol, pentachloro-	Elementary flows/Emission to air/high population density	Mass	kg	4.52E-11
Phosphorus	Elementary flows/Emission to air/high population density	Mass	kg	0.00000168
Phosphorus	Elementary flows/Emission to water/river	Mass	kg	0.000021
Potassium	Elementary flows/Emission to air/high population density	Mass	kg	0.000131
Propane	Elementary flows/Emission to air/high population density	Mass	kg	0.000000201
Propionic acid	Elementary flows/Emission to air/high population density	Mass	kg	1.56E-08
Selenium	Elementary flows/Emission to air/high population density	Mass	kg	0.000000018
Sodium	Elementary flows/Emission to air/high population density	Mass	kg	0.00000838
Sulfur dioxide	Elementary flows/Emission to air/high population density	Mass	kg	0.00024

Suspended solids, unspecified	Elementary flows/Emission to water/river	Mass	kg	0.00059
TOC, Total Organic Carbon	Elementary flows/Emission to water/river	Mass	kg	0.0083
Toluene	Elementary flows/Emission to air/high population density	Mass	kg	0.00000188
Vanadium	Elementary flows/Emission to air/high population density	Mass	kg	0.0000039
Zinc	Elementary flows/Emission to air/high population density	Mass	kg	0.00000174

Unit Processes in BAU Product System

P Inputs/Outputs: EPS at Plant – RER

Inputs

Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided waste	Provider	Data quality entr	Description
Aluminium, 24% in bauxite, 11% in cr...	Resource/in ground	0.00018	kg		none				
Anhydrite, in ground	Resource/in ground	8.42270E-6	kg		none				
Barite, 15% in crude ore, in ground	Resource/in ground	1.29100E-6	kg		none				
Calcium carbonate, in ground	Resource/in ground	0.00039	kg		none				
Chromium, 25.5% in chromite, 11.6...	Resource/in ground	2.33420E-8	kg		none				
Cinnabar, in ground	Resource/in ground	8.97920E-9	kg		none				
Clay, bentonite, in ground	Resource/in ground	8.28780E-5	kg		none				
Clay, unspecified, in ground	Resource/in ground	1.15380E-7	kg		none				
Coal, brown, in ground	Resource/in ground	3.08970E-5	kg		none				
Coal, hard, unspecified, in ground	Resource/in ground	0.14630	kg		none				
Copper, 0.99% in sulfide, Cu 0.36%...	Resource/in ground	0.00019	kg		none				
disposal, average incineration residu...	waste management/residual...	0.01549	kg		none				
disposal, facilities, chemical producti...	waste management/building d...	0.00011	kg		none				
disposal, hazardous waste, 25% wat...	waste management/hazardou...	0.01197	kg		none				
disposal, municipal solid waste, 22.9...	waste management/municipal...	0.02695	kg		none				
disposal, plastics, mixture, 15.3% wa...	waste management/municipal...	0.00190	kg		none				
disposal, spoil from coal mining, in s...	waste management/others	0.04555	kg		none				
disposal, tailings from hard coal milli...	waste management/others	0.00788	kg		none				
disposal, wood untreated, 20% water...	waste management/municipal...	0.00012	kg		none				

Outputs

Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided product	Provider	Data quality entr	Description
Acidity, unspecified	Emission to water/river	7.82090E-6	kg		none				
Aldehydes, unspecified	Emission to air/high populatio...	1.08050E-13	kg		none				
Aluminium	Emission to water/river	1.17460E-6	kg		none				
Ammonia	Emission to air/high populatio...	7.34790E-9	kg		none				
Ammonium, ion	Emission to water/river	2.93160E-5	kg		none				
Antimony	Emission to air/high populatio...	3.33410E-11	kg		none				
AOX, Adsorbable Organic Halogen as Cl	Emission to water/river	6.04500E-8	kg		none				
Arsenic	Emission to air/high populatio...	1.02310E-8	kg		none				
Arsenic, ion	Emission to water/river	8.28690E-10	kg		none				
Benzene	Emission to air/high populatio...	1.82570E-5	kg		none				
Benzene	Emission to water/river	1.62720E-6	kg		none				
Benzene, ethyl-	Emission to air/high populatio...	5.30460E-6	kg		none				
BOD5, Biological Oxygen Demand	Emission to water/river	0.00027	kg		none				
Bromate	Emission to water/river	3.28080E-9	kg		none				
Cadmium	Emission to air/high populatio...	1.15620E-9	kg		none				
Cadmium, ion	Emission to water/river	2.91650E-11	kg		none				
Calcium, ion	Emission to water/river	1.63300E-5	kg		none				
Carbon dioxide, biogenic	Emission to air/high populatio...	0.00509	kg		none				
Carbon dioxide, fossil	Emission to air/high populatio...	2.54050	kg		none				

General information | Inputs/Outputs | Administrative information | Modeling and validation | Parameters | Allocation | Social aspects | Impact analysis

Unit Processes in Alternative Product System

Inputs/Outputs: PLA coated liquid packaging board, at plant – RER

Inputs

Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided waste	Provider	Data quality entr	Description
chemicals inorganic, at plant - GLO	chemicals/inorganics	0.01200	kg		lognormal: gm...				
chips, Scandinavian softwood (plant-...	wooden materials/extraction	0.00022	m3		lognormal: gm...				
disposal, hazardous waste, 0% water...	waste management/undergro...	0.00013	kg		lognormal: gm...				
disposal, wood ash mixture, pure, 0%...	waste management/sanitary l...	0.03800	kg		lognormal: gm...				
electricity, medium voltage, producti...	electricity/production mix	0.72000	kWh		lognormal: gm...				
electricity, medium voltage, producti...	electricity/production mix	0.18000	kWh		lognormal: gm...				
heavy fuel oil, at regional storage - RER	oil/fuels	0.03640	kg		lognormal: gm...				
industrial residue wood, softwood, fo...	wooden materials/extraction	5.50000E-5	m3		lognormal: gm...				
industrial wood, hardwood, under bar...	wooden materials/extraction	0.00017	m3		lognormal: gm...				
industrial wood, Scandinavian hardw...	wooden materials/extraction	0.00067	m3		lognormal: gm...				
industrial wood, Scandinavian softwo...	wooden materials/extraction	0.00130	m3		lognormal: gm...				
industrial wood, softwood, under bar...	wooden materials/extraction	0.00032	m3		lognormal: gm...				
kaolin, at plant - RER	chemicals/inorganics	0.06700	kg		lognormal: gm...				
natural gas, high pressure, at consu...	natural gas/fuels	0.78100	MJ		lognormal: gm...				
oxygen, liquid, at plant - RER	chemicals/inorganics	0.00500	kg		lognormal: gm...				
paper mill, integrated - RER	paper & cardboard/graphic paper	5.44000E-11	Item(s)		lognormal: gm...				
polylactide, granulate, at plant - GLO	plastics/polymers	1.00000	kg		none				
quicklime, milled, loose, at plant - CH	construction materials/additives	0.00900	kg		lognormal: gm...				
sodium chlorate, powder, at plant - RER	chemicals/inorganics	0.00770	kg		lognormal: gm...				

Outputs

Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided product	Provider	Data quality entr	Description
Acetaldehyde	Emission to air/high populatio...	5.66000E-7	kg		lognormal: gm...				
Acetic acid	Emission to air/high populatio...	1.02000E-6	kg		lognormal: gm...				
Acetone	Emission to air/high populatio...	2.25000E-7	kg		lognormal: gm...				
Ammonia	Emission to air/high populatio...	9.67000E-6	kg		lognormal: gm...				
AOX, Adsorbable Organic Halogen as Cl	Emission to water/river	4.59000E-5	kg		lognormal: gm...				
Arsenic	Emission to air/high populatio...	2.51000E-8	kg		lognormal: gm...				
Benzene	Emission to air/high populatio...	5.39000E-6	kg		lognormal: gm...				
Benzene, ethyl-	Emission to air/high populatio...	1.68000E-7	kg		lognormal: gm...				
Benzene, hexachloro-	Emission to air/high populatio...	4.02000E-14	kg		lognormal: gm...				
Benzo(a)pyrene	Emission to air/high populatio...	2.84000E-9	kg		lognormal: gm...				
BOD5, Biological Oxygen Demand	Emission to water/river	0.00197	kg		lognormal: gm...				
Bromine	Emission to air/high populatio...	3.35000E-7	kg		lognormal: gm...				
Butane	Emission to air/high populatio...	5.47000E-7	kg		lognormal: gm...				
Cadmium	Emission to air/high populatio...	5.34000E-8	kg		lognormal: gm...				
Calcium	Emission to air/high populatio...	3.28000E-5	kg		lognormal: gm...				
Carbon dioxide, biogenic	Emission to air/high populatio...	0.53000	kg		lognormal: gm...				
Carbon dioxide, fossil	Emission to air/high populatio...	0.15600	kg		lognormal: gm...				
Carbon monoxide, biogenic	Emission to air/high populatio...	0.00027	kg		lognormal: gm...				
Carbon monoxide, fossil	Emission to air/high populatio...	1.21000E-5	kg		lognormal: gm...				

General information | Inputs/Outputs | Administrative information | Modeling and validation | Parameters | Allocation | Social aspects | Impact analysis

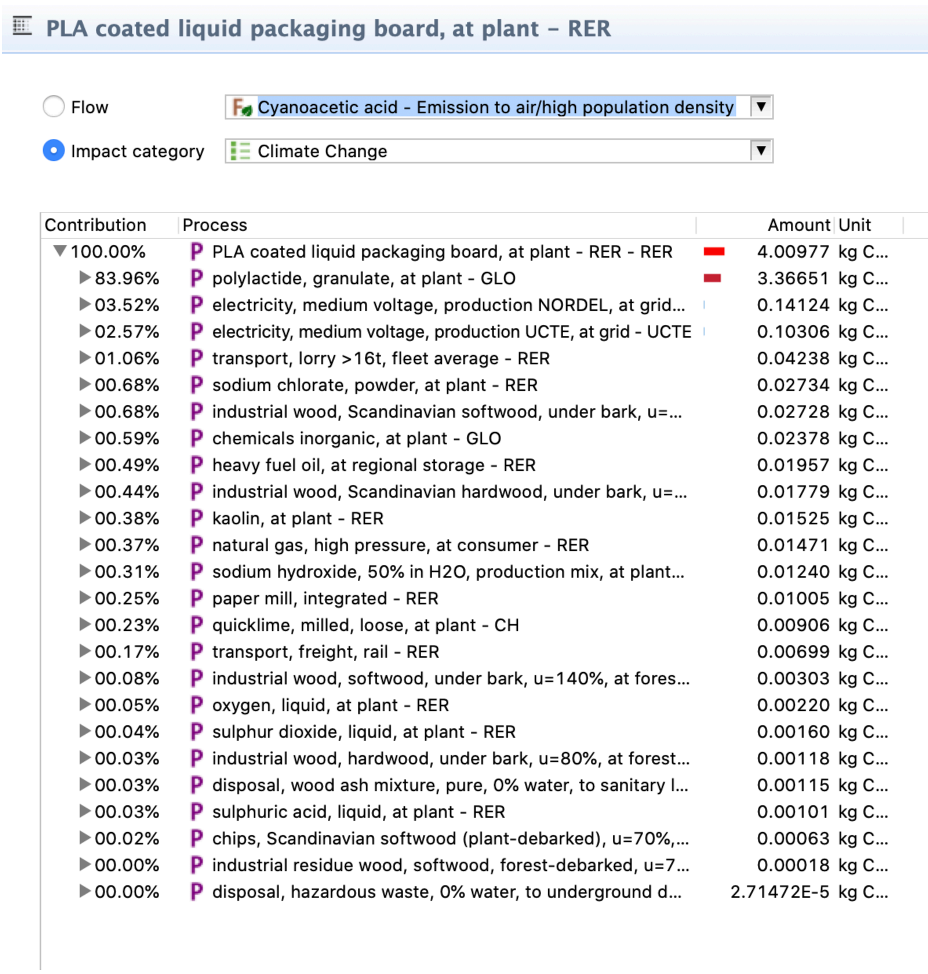
BAU vs Alternative Contribution Tree - Climate Change

EPS at Plant – RER

○ Flow: Cyanoacetic acid - Emission to air/high population density

● Impact category: Climate Change

Contribution	Process	Amount	Unit
▼100.00%	EPS at Plant - RER - RER	5.59991	kg C...
▶13.35%	foaming, expanding - RER	0.74757	kg C...
▶00.53%	disposal, hazardous waste, 25% wa...	0.02960	kg C...
▶00.24%	disposal, municipal solid waste, 22....	0.01366	kg C...
▶00.10%	disposal, average incineration resid...	0.00532	kg C...
▶00.08%	disposal, plastics, mixture, 15.3%...	0.00446	kg C...
▶00.00%	disposal, facilities, chemical produc...	7.13327E-6	kg C...
▶00.00%	disposal, wood untreated, 20% wat...	1.54211E-6	kg C...
00.00%	disposal, spoil from coal mining, in...	0.00000	kg C...
00.00%	disposal, tailings from hard coal mil...	0.00000	kg C...



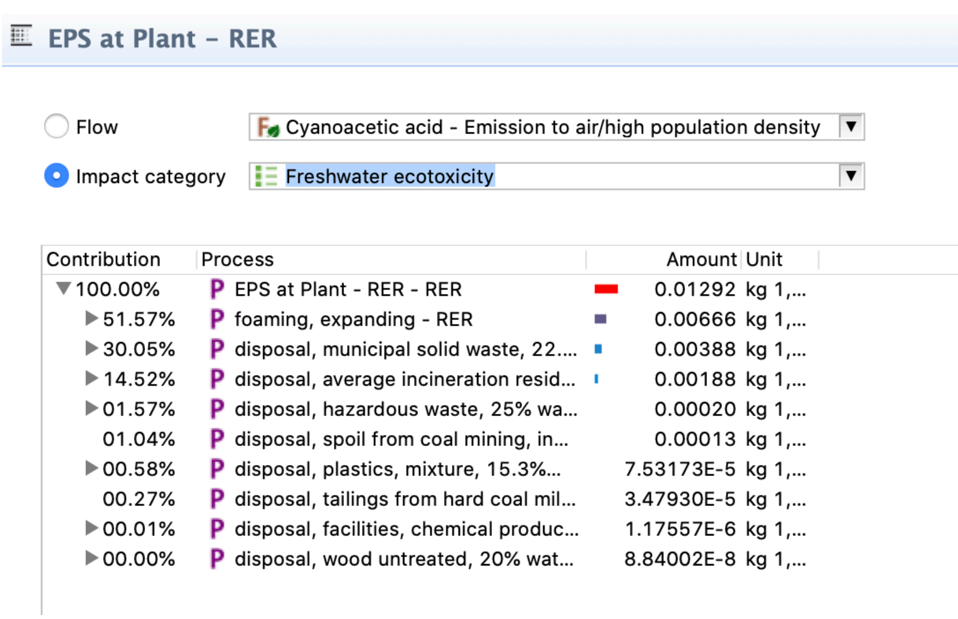
PLA coated liquid packaging board, at plant - RER

Flow: Cyanoacetic acid - Emission to air/high population density

Impact category: Climate Change

Contribution	Process	Amount	Unit
100.00%	PLA coated liquid packaging board, at plant - RER - RER	4.00977	kg C...
83.96%	polylactide, granulate, at plant - GLO	3.36651	kg C...
03.52%	electricity, medium voltage, production NORDEL, at grid...	0.14124	kg C...
02.57%	electricity, medium voltage, production UCTE, at grid - UCTE	0.10306	kg C...
01.06%	transport, lorry >16t, fleet average - RER	0.04238	kg C...
00.68%	sodium chlorate, powder, at plant - RER	0.02734	kg C...
00.68%	industrial wood, Scandinavian softwood, under bark, u=...	0.02728	kg C...
00.59%	chemicals inorganic, at plant - GLO	0.02378	kg C...
00.49%	heavy fuel oil, at regional storage - RER	0.01957	kg C...
00.44%	industrial wood, Scandinavian hardwood, under bark, u=...	0.01779	kg C...
00.38%	kaolin, at plant - RER	0.01525	kg C...
00.37%	natural gas, high pressure, at consumer - RER	0.01471	kg C...
00.31%	sodium hydroxide, 50% in H2O, production mix, at plant...	0.01240	kg C...
00.25%	paper mill, integrated - RER	0.01005	kg C...
00.23%	quicklime, milled, loose, at plant - CH	0.00906	kg C...
00.17%	transport, freight, rail - RER	0.00699	kg C...
00.08%	industrial wood, softwood, under bark, u=140%, at fores...	0.00303	kg C...
00.05%	oxygen, liquid, at plant - RER	0.00220	kg C...
00.04%	sulphur dioxide, liquid, at plant - RER	0.00160	kg C...
00.03%	industrial wood, hardwood, under bark, u=80%, at forest...	0.00118	kg C...
00.03%	disposal, wood ash mixture, pure, 0% water, to sanitary l...	0.00115	kg C...
00.03%	sulphuric acid, liquid, at plant - RER	0.00101	kg C...
00.02%	chips, Scandinavian softwood (plant-debarked), u=70%,...	0.00063	kg C...
00.00%	industrial residue wood, softwood, forest-debarked, u=7...	0.00018	kg C...
00.00%	disposal, hazardous waste, 0% water, to underground d...	2.71472E-5	kg C...

BAU vs Alternative Contribution Tree - Freshwater Ecotoxicity



EPS at Plant - RER

Flow: Cyanoacetic acid - Emission to air/high population density

Impact category: Freshwater ecotoxicity

Contribution	Process	Amount	Unit
100.00%	EPS at Plant - RER - RER	0.01292	kg 1,...
51.57%	foaming, expanding - RER	0.00666	kg 1,...
30.05%	disposal, municipal solid waste, 22....	0.00388	kg 1,...
14.52%	disposal, average incineration resid...	0.00188	kg 1,...
01.57%	disposal, hazardous waste, 25% wa...	0.00020	kg 1,...
01.04%	disposal, spoil from coal mining, in...	0.00013	kg 1,...
00.58%	disposal, plastics, mixture, 15.3%...	7.53173E-5	kg 1,...
00.27%	disposal, tailings from hard coal mil...	3.47930E-5	kg 1,...
00.01%	disposal, facilities, chemical produc...	1.17557E-6	kg 1,...
00.00%	disposal, wood untreated, 20% wat...	8.84002E-8	kg 1,...

PLA coated liquid packaging board, at plant – RER

Flow: Cyanoacetic acid - Emission to air/high population density

Impact category: Freshwater ecotoxicity

Contribution	Process	Amount	Unit
▼100.00%	P PLA coated liquid packaging board, at plant - RER - RER	0.03730	kg 1,...
▶76.27%	P polylactide, granulate, at plant - GLO	0.02845	kg 1,...
▶12.52%	P disposal, wood ash mixture, pure, 0% water, to sanitary l...	0.00467	kg 1,...
▶03.95%	P electricity, medium voltage, production UCTE, at grid - UCTE	0.00147	kg 1,...
▶01.63%	P electricity, medium voltage, production NORDEL, at grid...	0.00061	kg 1,...
▶01.42%	P sodium chlorate, powder, at plant - RER	0.00053	kg 1,...
▶01.22%	P paper mill, integrated - RER	0.00046	kg 1,...
▶00.58%	P chemicals inorganic, at plant - GLO	0.00022	kg 1,...
▶00.53%	P sodium hydroxide, 50% in H2O, production mix, at plant...	0.00020	kg 1,...
▶00.33%	P transport, lorry >16t, fleet average - RER	0.00012	kg 1,...
▶00.29%	P heavy fuel oil, at regional storage - RER	0.00011	kg 1,...
▶00.26%	P kaolin, at plant - RER	9.59379E-5	kg 1,...
▶00.25%	P industrial wood, Scandinavian softwood, under bark, u=...	9.22186E-5	kg 1,...
▶00.21%	P transport, freight, rail - RER	7.70791E-5	kg 1,...
▶00.16%	P industrial wood, Scandinavian hardwood, under bark, u=...	5.89784E-5	kg 1,...
▶00.08%	P oxygen, liquid, at plant - RER	3.15875E-5	kg 1,...
▶00.07%	P industrial wood, softwood, under bark, u=140%, at fores...	2.48697E-5	kg 1,...
▶00.06%	P sulphur dioxide, liquid, at plant - RER	2.08744E-5	kg 1,...
▶00.05%	P sulphuric acid, liquid, at plant - RER	1.80347E-5	kg 1,...
▶00.03%	P industrial wood, hardwood, under bark, u=80%, at forest...	9.85151E-6	kg 1,...
▶00.02%	P chips, Scandinavian softwood (plant-debarked), u=70%,...	7.30347E-6	kg 1,...
▶00.02%	P natural gas, high pressure, at consumer - RER	6.58538E-6	kg 1,...

BAU vs Alternative Contribution Tree - Human Toxicity

EPS at Plant – RER

Flow: Cyanoacetic acid - Emission to air/high population density

Impact category: Human toxicity

Contribution	Process	Amount	Unit
▼100.00%	P EPS at Plant - RER - RER	0.02819	kg 1,...
▶68.36%	P foaming, expanding - RER	0.01927	kg 1,...
▶07.48%	P disposal, average incineration resid...	0.00211	kg 1,...
▶03.23%	P disposal, hazardous waste, 25% wa...	0.00091	kg 1,...
▶01.24%	P disposal, municipal solid waste, 22....	0.00035	kg 1,...
00.31%	P disposal, spoil from coal mining, in...	8.71089E-5	kg 1,...
00.17%	P disposal, tailings from hard coal mil...	4.80245E-5	kg 1,...
▶00.13%	P disposal, plastics, mixture, 15.3%...	3.74174E-5	kg 1,...

PLA coated liquid packaging board, at plant – RER

- Flow: Cyanoacetic acid - Emission to air/high population density
- Impact category (selected): Human toxicity

Contribution	Process	Amount	Unit
100.00%	PLA coated liquid packaging board, at plant - RER - RER	0.07962	kg 1,...
56.40%	polylactide, granulate, at plant - GLO	0.04491	kg 1,...
05.47%	disposal, wood ash mixture, pure, 0% water, to sanitary l...	0.00436	kg 1,...
04.22%	sodium hydroxide, 50% in H2O, production mix, at plant...	0.00336	kg 1,...
02.47%	electricity, medium voltage, production NORDEL, at grid...	0.00197	kg 1,...
02.26%	electricity, medium voltage, production UCTE, at grid - UCTE	0.00180	kg 1,...
01.65%	chemicals inorganic, at plant - GLO	0.00131	kg 1,...
01.21%	paper mill, integrated - RER	0.00096	kg 1,...
01.17%	transport, lorry >16t, fleet average - RER	0.00093	kg 1,...
00.80%	sodium chlorate, powder, at plant - RER	0.00063	kg 1,...
00.67%	industrial wood, Scandinavian softwood, under bark, u=...	0.00053	kg 1,...
00.61%	heavy fuel oil, at regional storage - RER	0.00049	kg 1,...
00.48%	kaolin, at plant - RER	0.00038	kg 1,...
00.43%	industrial wood, Scandinavian hardwood, under bark, u=...	0.00034	kg 1,...
00.40%	transport, freight, rail - RER	0.00032	kg 1,...
00.11%	natural gas, high pressure, at consumer - RER	8.52128E-5	kg 1,...
00.10%	industrial wood, softwood, under bark, u=140%, at fores...	8.30138E-5	kg 1,...
00.06%	sulphur dioxide, liquid, at plant - RER	4.63930E-5	kg 1,...
00.06%	sulphuric acid, liquid, at plant - RER	4.53297E-5	kg 1,...
00.05%	oxygen, liquid, at plant - RER	3.87308E-5	kg 1,...
00.04%	industrial wood, hardwood, under bark, u=80%, at forest...	3.36121E-5	kg 1,...
00.04%	chips, Scandinavian softwood (plant-debarked), u=70%,...	2.79985E-5	kg 1,...
00.01%	quicklime, milled, loose, at plant - CH	1.09886E-5	kg 1,...
00.01%	industrial residue wood, softwood, forest-debarked, u=7...	5.34794E-6	kg 1,...
00.00%	disposal, hazardous waste, 0% water, to underground d...	1.02680E-6	kg 1,...

BAU vs Alternative Normalization and Weighting

EPS at Plant – RER

Normalization

Impact category	Amount
Marine ecotoxicity	0.00410
Freshwater ecotoxicity	0.00300
Freshwater eutrophication	0.00183
Fossil depletion	0.00163
Climate Change	0.00059
Ionising radiation	0.00055
Photochemical oxidant formation	0.00040
Terrestrial acidification	0.00035
Particulate matter formation	0.00029

PLA coated liquid packaging board, at plant - RER

Normalization

Impact category	Amount
Marine ecotoxicity	0.01106
Freshwater ecotoxicity	0.00867
Freshwater eutrophication	0.00618
Ionising radiation	0.00217
Agricultural land occupation	0.00179
Marine eutrophication	0.00159
Terrestrial ecotoxicity	0.00130
Fossil depletion	0.00086
Climate Change	0.00042