Life Cycle Assessment:

Comparative LCA of the Environmental Impacts of Real Christmas and Artificial Christmas trees.

Study Completed: October 2017

Critical Review Completed: March 2018

Public Version 2018

WAP Sustainability Consulting, LLC.
info@wapsustainability.com

Table of Contents

EXECUTIVE SUMMARY

The American Christmas Tree Association (ACTA) commissioned this comparative LCA study in order to compare the life cycle impacts of artificial Christmas trees and real Christmas trees. According to their website, "The American Christmas Tree Association is a non-profit organization whose mission is to educate the public with factual data to help consumers make intelligent decisions about Christmas trees and the Christmas tree industry". This LCA was conducted in order to compare the life cycle impacts of artificial Christmas trees and real Christmas trees. The results will be used to make public statements about the environmental footprint of the two products.

For this study, the functional unit was considered as one Christmas tree used for one season. The artificial tree that was modeled in this study was manufactured in China and shipped to the United States to be distributed by major big box retailers. The artificial tree included in this study was 1.98 m (6.5-ft) tall and weighs 4.93 kg (10.86 lbs). This weight includes the tree itself and the tree stand shipped with the product but does not include the weight of the packaging. The material composition of the artificial Christmas trees is a mixture of plastics and metals while the packaging of the trees is comprised of cardboard, tape and paper and is included in the study. For this study, it is assumed that the artificial Christmas tree is landfilled at the end of the its useful life.

The real Christmas tree modeled in this comparative LCA study used a 1.98 m (6.5-ft) Fraser fir to represent the growing, harvesting and distribution pattern of real Christmas trees sold in the United States. The real Christmas tree is assumed to be grown in Southeastern United States. The cultivation period includes 7 years of field growth. Packaging of baling and string were included in the study. The use phase of the real Christmas tree involves watering the tree.

Transportation of raw materials to the manufacturing/cultivation site, shipping to the customer and transportation to the disposal site are also considered in this study for both trees. Additionally, the necessary tree stand is included for both products and is assumed to be reused annually. Tree lights and ornaments are excluded from this study. For the artificial Christmas tree, various use scenarios were considered since the lifetime of the product is at the customer's discretion. The use scenarios compared 1 year of using the artificial Christmas tree and the real Christmas tree, 5 years of using an artificial tree and using 5 real Christmas trees over 5 years and finally 10 years of using an artificial Christmas tree and using 10 real Christmas trees over 10 years. Since disposal options for real Christmas trees can vary by location and customer preference, three different end-of-life scenarios were considered for the real Christmas tree. These end-of-life scenarios included landfilling, composting and incineration.

WAP Sustainability Consulting, LLC was contracted to develop the LCA model using the GaBi 8 software platform. Brad McAllister of WAP Sustainability Consulting, LLC was the lead project manager. Matt Van Duinen and Manasa Kovvali Rao also provided consultant support.

As this is a comparative LCA in which the results will be used for public disclosure, a three-person critical review panel was formed. The following individuals were selected for the review panel.

- Dr. Tom Gloria- LCA Panel Chair, Program Director, Sustainability, Harvard University, Division of Continuing Education
- Dr. Eric Hinesley - Professor Emeritus, Department of Horticultural Science, North Carolina State University

- Mike Levy - Senior Director, American Chemistry Council, Life Cycle Issues and Plastics Foodservice Packaging Group

Results

The results of this Study show that the choices made by the customer are a significant contributor to the impacts of both Christmas trees. For the real Christmas tree customer, the manner in which the tree is disposed of at the end of its life is a major contributor to the impacts of the real Christmas tree. For the artificial Christmas tree customer, the length of use is the primary contributor to the artificial Christmas tree impacts.

For the real Christmas tree, cultivation (planting, fertilizing, watering, etc.) is the largest contributor of environmental impacts, with one exception. The end-of-life phase of the real Christmas tree results in the largest contribution of greenhouse gas emissions in the real Christmas tree's life cycle. This difference is, in part, due to modeling decisions concerning the handling of carbon sequestration in the cultivation phase and carbon release in the end-of-life stage.

For the artificial tree, the raw materials used in manufacturing, specifically polyvinylchloride followed by steel sheets, comprises the largest source of impacts in the artificial tree. Among the various life cycle phases, raw materials and transportation are seen to have largest impacts. Raw materials are primarily responsible for greenhouse gas emissions, eutrophication of water sources and use of non-renewable energy. Transportation mainly causes acidification of water, air and soil and smog in the atmosphere.

Given the quantification of environmental impacts across both of the trees' life cycles, a comparative assertion shows the breakeven point between the two trees is 4.7 years. That is to say an artificial tree purchased and used for at least 4.7 years demonstrates a lower contribution to environmental impact than 4.7 real Christmas trees purchased over 4.7 years. This assertion considers all end of life scenarios for the real Christmas tree, and assumes that a customer of an artificial tree would purchase the tree and keep it for 5 or more years. The breakeven point can change based on the environmental metrics and end-of-life scenarios, but considering the most conservative calculations, purchasing an artificial tree and keeping it for 4.7 years is less environmentally impactful than purchasing the equivalent amount of real Christmas trees.

In 2010, a life cycle assessment by PE Americas was conducted to compare the impacts associated with a real Christmas and an artificial Christmas tree. The PE Americas LCA studied the differences in impacts for both trees over a similar period of time. The results of the PE America's Study demonstrated similar results to the study completed by WAP Sustainability Consulting, LLC.. However, the results of these two studies must not be compared directly. This incomparability stems from several key elements, mostly owing to differences in methodology, and include:

1) Different LCA practitioners from two different companies conducted the studies.
2) Availability and quality of background data (GaBi datasets) has changed in the past 7 years.
3) Possible differences in handling and modeling biogenic carbon sinks during cultivation and carbon releases during end-of-life.

Despite the two studies' limited comparability, the results of the two studies do support some important and consistent generalizations. These are basic trends that can be understood by looking at both of the reports individually and include:

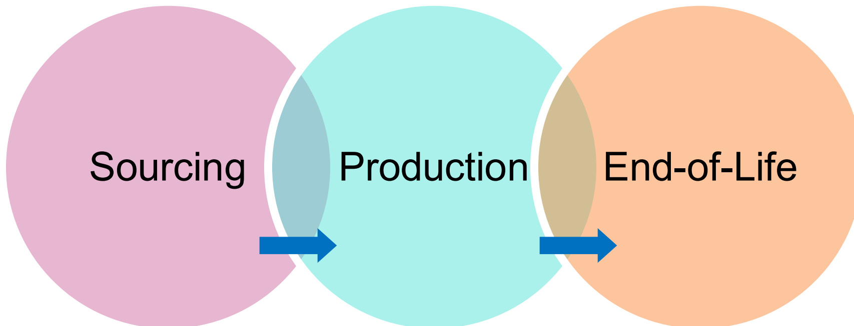
1) Both studies indicate that the impacts of sourcing of raw materials is the number one contributor to the environmental impacts across all categories for the artificial tree.
2) Both studies indicate that End-of-life treatment options for real Christmas trees significantly impact the overall footprint of these trees.
3) Both studies indicate a roughly 5-year average breakeven point favoring the artificial Tree as a comparative assertion, given the customer keeps the artificial Tree for at least 5 years.

Conclusion

This LCA was conducted in order to compare the life cycle impacts of artificial Christmas trees and real Christmas trees. The results demonstrate that on a one-to-one comparison, one real Christmas tree generates fewer environmental impacts than one artificial Tree. This statement considers all end of life variables for both trees across all life cycle impact categories.

The study also assumed that reasonable customers do not purchase an artificial tree and use it for only one year. The study demonstrated that if a customer purchases an artificial tree and used it for at least 4.7 years, vs. purchasing the equivalent (4.7) real Christmas trees, the environmental burden shifts and the artificial tree would generate fewer environmental impacts.

Public Statements about the study will aim to educate customers that the purchase of an artificial Christmas tree is environmental beneficial to real Christmas trees, provided the customer keeps the tree for at least five years.



General Information

LCA Commissioners and Practitioners

The American Christmas Tree Association (ACTA) commissioned this comparative LCA study. According to their website, "The American Christmas Tree Association is a non-profit organization whose mission is to educate the public with factual data to help consumers make intelligent decisions about Christmas Trees and the Christmas Tree industry."

WAP Sustainability Consulting was contracted to develop the LCA model using the GaBi 8 software platform. Associates from WAP Sustainability prepared this report. Brad McAllister of WAP Sustainability Consulting was the lead project manager. Matt Van Duinen and Manasa Kovvali Rao also provided consultant support. All three consultants are Life Cycle Assessment Certified Practitioners (LCACP) through the American Center for Lifecycle Assessment (ACLCA).

Since this is a comparative LCA in which the results will be used for public disclosure, a three-person critical review panel was formed. WAP Sustainability Consulting identified the panel members of the review committee. The panel represents a cross section of expertise that includes Christmas Tree horticulture, plastics chemistry and Life Cycle Assessment. The following individuals were selected for the review panel.

- Dr. Tom Gloria- LCA Panel Chair, Program Director, Sustainability, Harvard University, Division of Continuing Education
- Dr. Eric Hinesley - Professor Emeritus, Department of Horticultural Science, North Carolina State University
- Mike Levy - Senior Director, American Chemistry Council, Life Cycle Issues and Plastics Foodservice Packaging Group

Dr. Hinesley and Mr. Levy were participants in the 2010 Report, *Comparative Life Cycle Assessment of an artificial Christmas tree and a real Christmas tree.* That report was also commissioned by ACTA and serves as the predecessor to this one.

Reporting Date

This LCA study was commenced in May 2017 and a draft was submitted for critical review in October 2017. The final approval of the document occurred in November 2017.

Goal and Scope of the Study

Reason(s) for carrying out the study and Intended Application

The American Christmas Tree Association (ACTA) commissioned this comparative LCA study. According to their website, “The American Christmas Tree Association is a non-profit organization whose mission is to educate the public with factual data to help consumers make intelligent decisions about Christmas trees and the Christmas tree industry.” This LCA was conducted in order to compare the life cycle impacts of artificial Christmas trees and real Christmas trees. The results will be used to make public statements about the environmental footprint of the two products. It is expected that the statements will be made online, in print in various publications and media and potentially on radio and television outlets.

Target Group / Audience

The target audience of this report includes the general public and member companies of the ACTA. It is anticipated that the results of the study will be used for public statements to perspective Christmas Tree customers and the media.

ISO 14040-44 and PCR Compliance

This LCA has been critically reviewed for ISO14040/44 compliance to assure adherence to the requirements of comparative LCAs.

Please see Appendix A for Compliance Statement.

Product System Definition

This LCA models both an artificial Christmas tree and a real Christmas tree.

Artificial Tree

The artificial tree that was modeled in this study is representative of the most commonly manufactured and sold artificial Christmas tree in the United States. The representative artificial tree is 6.5-ft. (1.98 m) tall and weighs 4.93 kg (10.86 lbs). This weight includes the tree stand that is shipped with the product but does not include packaging. The artificial tree is manufactured in China and shipped to the United States to be distributed by major big box retailers. The material composition of the product is a mixture of plastics and metals. For instance, the trunk of the tree is primarily PVC and the branches are polypropylene wrapped around steel. The included tree stand is made of both steel and plastics. Packaging includes cardboard, tape and paper and is included in this LCA study.

Resources are consumed during the manufacturing of the artificial Christmas tree, including electricity, thermal energy from biomass and real Christmas gas, and water. Additionally, waste is generated. Generally, plastic waste is recycled in-house to be utilized in future manufacturing. Metal waste is sold to qualified recycling companies. When generated, packaging waste from cardboard and paper is also recycled.

Transportation impacts were evaluated both upstream and downstream from the manufacturing process. For upstream impacts, the distances and shipping methodologies from suppliers were evaluated. For downstream impacts, evaluation includes the transportation to customers. This includes the transport of the final product to shipping harbor, the transport by sea vessel from the Chinese port to the receiving port in the US, and transportation of the tree from the receiving harbor to the retail facility. Additionally, the travel of customers to the retail facility and back home was evaluated.

It is assumed that the artificial Christmas tree is landfilled at the end of the its useful life. Landfill impacts will be evaluated by estimating the distance that the tree travels from the customer's home to the landfill and by using GaBi datasets for the landfilling of plastic and metal products.

Sourcing, manufacturing and distribution data were provided by the primary manufacturer and supplier of artificial Christmas trees in the United States.

Real Christmas tree

This comparative LCA study uses a Fraser fir to represent the growing, harvesting and distribution pattern of real Christmas trees sold in the United States. Data used to represent the product life cycle of the Fraser fir was collected through a comprehensive literature review supplemented with industry data. To assure an equivalent product system for comparative purposes with the artificial tree, a 6.5-ft. (1.98 m) Fraser fir tree was modeled. Additionally, it is assumed that the tree is distributed to customers through the retail market.

The Fraser fir considered is grown on a tree farm in the southeast of the United States.

Also included in the product system of the real Christmas tree is the tree stand necessary for the customer to enjoy the Christmas Tree in his/her home.

Functional unit

The basis of an LCA study is the functional unit. For this study, the functional unit is considered one Christmas Tree, 6.5-ft. (1.98 m) in height. The necessary tree stand is included for both products. However, tree lights and ornaments are not included. It is assumed that the lights and ornaments for the two trees would be equivalent.

The time boundary of the functional unit must be considered. Under all scenarios, it is assumed that the real Christmas tree is used for one year. For the artificial Christmas tree, various use scenarios will be considered since the lifetime of the product is at the customer's discretion. These scenarios are listed below. In each of these scenarios it is also assumed that the tree stand for the real Christmas tree has a product lifetime of 10 years.

- **1-Year:** This scenario assumes that the artificial tree and tree stand is used for 1 year. In this scenario, the lifecycle of 1 artificial Christmas tree is equal to 1 real Christmas tree and 1/10 of the real Christmas C Tree's stand.
- **5-Year:** This scenario assumes that the artificial tree and tree stand is used for 5 years. In this scenario, the lifecycle of 1 artificial Christmas tree is equal to 5 real Christmas trees and 1/2 of the real Christmas tree's stand.
- **10-Year:** This scenario assumes that the artificial tree and tree stand is used for 10 years. In this scenario, the lifecycle of 1 artificial Christmas tree is equal to 10 real Christmas trees and 1 real Christmas tree's stand.

SYSTEM BOUNDARY

This LCA study will be designed to consider the cradle-to-grave impacts of sourcing, distribution, use and disposal of the real Christmas and artificial Christmas trees. These stages have been categorized to match the original LCA study.

Table 1: Summary of Included Life Cycle Stages

Module Name	Summary of Included Elements for the artificial Tree	Summary of Included Elements for the real Christmas tree
Manufacturing/Cultivat	This stage includes the sourcing of raw materials, the production of tree components, the assembly of the tree, and packaging for retail and shipment. This phase also includes the impacts associated with the manufacture of the tree stand.	This stage includes the cultivation of the real Christmas tree and will include such elements as planting the seed, operation of a greenhouse, on-farm transportation and packaging, plantation inputs and harvesting the full grown tree. Packaging to prepare the tree for shipping is included. This phase also includes the impacts associated with the manufacture of the tree stand.

ion		
FinishedTreetoHome	This phase includes the transport of the tree to the customer. This includes the shipping of the product from China to the US, the shipping of the product to the retail store and the transportation of the customer to and from the retail store to purchase and transport the tree to his/her home. Disposal of packaging necessary for shipping is included in this stage. Overhead inputs of the retailer (such as energy for lights and transportation of employees) are not included.	This phase includes transporting the real Christmas tree from the plantation to the retailer via truck. This stage also includes the customer's transportation to and from the retail store to purchase and transport the tree to his/her home. Disposal of packaging necessary for shipping is included in this stage. Overhead inputs of the retailer (such as energy for lights and transportation of employees) are not included.
UsePhase	In this phase, it is assumed that the customer sets the tree up in his/her home. As such, disposal of packaging is included in this stage.	In this phase, it is assumed that the customer sets the tree up in his/her home. As such, disposal of packaging is included in this stage. Although a small number of live trees are packaged in cardboard boxes for mail order, this study evaluates only the predominate packaging methods of live trees, which includes only twine used to bail the real Christmas tree. Additionally, included in this phase is the use of water to maintain the tree for the Christmas season.
End-of-Life	The EoL phase of the LCA considers the shipping of the artificial tree to the landfill and the impacts associated with the landfilling the tree.	Handling of a real Christmas tree can vary based on location and preference of the customer. Primarily, there are three end-of-life pathways. These include, landfilling, incineration and composting. This LCA will consider all three of these options.

CUT-OFF CRITERIA

All inputs in which data was available were included.

Material inputs greater than 1% (based on total mass of the final product) were included within the scope of analysis. Material inputs less than 1% were included if sufficient data was available to warrant inclusion and/or the material input was thought to have significant environmental impact. Cumulative excluded material inputs and environmental impacts are less than 5% based on total weight of the functional unit.

List of excluded materials and energy inputs include:

- As the hand tools used during the harvesting of the tree are multi-use tools and can be reused after each tree, the per-functional unit impacts are considered negligible and therefore aren't included.
- Some material and energy inputs may have been excluded within the GaBi datasets used for this project. All GaBi datasets have been critically reviewed and conform to the exclusion requirements of ISO 14040/44.

Data Quality Requirements

All data inputs will be evaluated for precision, completeness, consistency and representativeness. Precision indicates whether a data source is measured, calculated or estimated. Completeness indicates if there are any data gaps in the information used. Consistency indicates whether a data point was collected in a similar manner as other data points and if background data was developed using similar methodologies. Representativeness indicates how equivalent a data set is to real Christmas-world experience in the context of time, region and technology.

Representativeness of data quality is shown below.

High quality background data from thinkstep's GaBi LCA software platform was used to model upstream and downstream impacts where possible.

Background Data

Background data used in the study are listed in the table below. All data was sourced from GaBi datasets.

Table 2: Dataset References

Dataset	Source	Time Coverage	Geographic Coverage	Technological Coverage	Overall Representativeness
Process steam from real Christmas gas 90%	ts	Within 10 year period	US	Appropriate technology	Excellent
Electricity grid mix	ts	Within 10 year period	CN	Appropriate technology	Excellent
Electricity grid mix	ts	Within 10 year period	US	Appropriate technology	Excellent
Thermal energy from real Christmas gas	ts	Within 10 year period	CN	Appropriate technology	Excellent
Thermal energy from real Christmas gas	ts	Within 10 year period	US	Appropriate technology	Excellent
Lubricants at refinery	ts	Within 10 year period	JP	Appropriate technology	Great, appropriate technology but not correct geography
Lubricants at refinery	ts	Within 10 year period	US	Appropriate technology	Excellent
Heavy fuel oil at refinery (1.0 wt.% S)	ts	Within 10 year period	JP	Appropriate technology	Great, appropriate technology but not correct geography

Diesel mix at filling station	ts	Within 10 year period	CN	Appropriate technology	Excellent
Diesel mix at filling station	ts	Within 10 year period	US	Appropriate technology	Excellent
Gasoline mix (regular) at filling station	ts	Within 10 year period	US	Appropriate technology	Excellent
Compressed air 7 bar (high power consumption)	ts	Within 10 year period	GLO	Appropriate technology	Excellent
Polyethylene film (LDPE/PE-LD)	ts	Within 10 year period	US	Appropriate technology	Excellent
Polyethylene High Density Granulate (HDPE/PE-HD)	ts	Within 10 year period	US	Appropriate technology	Excellent
Polyvinyl chloride granulate (Suspension, S-PVC)	ts	Within 10 year period	US	Appropriate technology	Excellent
Ethylene/methacrylic acid ionomer (EMAA)	ts	Within 10 year period	US	Appropriate technology	Excellent
Acrylonitrile-Butadiene-Styrene Granulate (ABS)	ts	Within 10 year period	US	Appropriate technology	Excellent
Polypropylene granulate (PP)	ts	Within 10 year period	US	Appropriate technology	Excellent
Stainless steel - Cold rolled coil	ts-EPD	Within 10 year period	RER	Appropriate technology	Great, appropriate technology but not correct geography
Steel sheet EG	ts	Within 10 year period	DE	Appropriate technology	Great, appropriate technology but not correct geography
Limestone flour (1μm)	ts	Within 10 year period	US	Used as a proxy for calcium carbonate (fertilizer)	Good
Corrugated cardboard	BUWAL	More than 10 year period	CH	Appropriate technology	Excellent
Water deionized	ts	Within 10 year period	US	Appropriate technology	Excellent
Hydrochloric acid by product chlorobenzene	ts	Within 10 year period	US	Used as a proxy for Glyphosate	Good
Water deionized (reverse-osmosis/electro-deionization)	ts	Within 10 year period	US	Appropriate technology	Excellent
Ammonium sulphate, by product acrylonitrile, hydrocyanic acid	ts	Within 10 year period	US	Appropriate technology	Excellent
Magnesium sulfate (agrarian)	ts	Within 10 year period	CA	Appropriate technology	Excellent
Potassium chloride (agrarian)	ts	Within 10 year period	CA	Appropriate technology	Excellent
Phosphoric acid (54% P2O5, agrarian)	ts	Within 10 year period	US	Used as a proxy for phosphate fertilizer	Good
Plastic extrusion profile (unspecific)	ts	Within 10 year period	GLO	Appropriate technology	Excellent
Steel sheet stamping and bending (5% loss)	ts	Within 10 year period	GLO	Appropriate technology	Excellent
Plastic injection moulding part (unspecific)	ts	Within 10 year period	DE	Appropriate technology	Excellent
Truck - Trailer, basic enclosed / 45,000 lb payload - 8b	ts	Within 10 year period	US	Appropriate technology	Excellent
Truck - Dump Truck / 52,000 lb payload - 8b	ts	Within 10 year period	US	Appropriate technology	Excellent
Truck - Flatbed, platform, etc. / 49,000 lb payload - 8b	ts	Within 10 year period	US	Appropriate technology	Excellent
Truck, Euro 3, 20 - 26t gross weight / 17,3t payload capacity	ts	Within 10 year period	GLO	Appropriate technology	Excellent
Truck - Pole, logging, pulpwood, or pipe / 50,000 lb payload - 8b	ts	Within 10 year period	US	Appropriate technology	Excellent
Grocery transport by car	ts	Within 10 year period	US	Appropriate technology	Excellent
Container ship, 27500 dwt payload capacity, ocean going	ts	Within 10 year period	GLO	Appropriate technology	Excellent
Reforesting, high intensity site, US SE	USLCI/ts	Within 10 year period	US	Used for growth of tree from seed to young tree	Excellent

Ferro metals on landfill, post-consumer	ts	Within 10 year period	US	Appropriate technology	Excellent
Biodegradable waste on landfill, post-consumer	ts	Within 10 year period	US	Appropriate technology	Excellent
Plastic waste on landfill, post-consumer	ts	Within 10 year period	US	Appropriate technology	Excellent
Paper waste on landfill, post-consumer	ts	Within 10 year period	US	Appropriate technology	Excellent
Wood (real Christmas) in waste incineration plant	ts	Within 10 year period	DE	Appropriate technology	Excellent
Municipal waste water treatment (mix)	ts	Within 10 year period	US	Appropriate technology	Excellent
Joint sealing tape butyl (EN15804 A1-A3)	ts	Within 10 year period	DE	Appropriate technology	Great, appropriate technology but not correct geography
Epoxy resin	PlasticsEurope	Within 10 year period	RER	Appropriate technology	Great, appropriate technology but not correct geography
Steel wire rod	worldsteel	Within 10 year period	GLO	Appropriate technology	Great, appropriate technology but not correct geography

Data Collection and Calculation Procedures

All calculation procedures adhere to ISO14044. Collection and processing of major data points is described in the subsequent sections of this report.

Allocation Procedures

General principles of allocation were based on ISO14044. Where possible, allocation was avoided. When allocation was necessary it was done on a physical mass basis. Allocation was most prevalent in the secondary GaBi datasets used to represent upstream processes. As a default, GaBi datasets use a physical mass basis for allocation.

Parameters Describing Environmental Impacts

Environmental Impacts were calculated using the GaBi software platform (version 8). Impact results were calculated using TRACI 2.1 characterization factors.

There was no normalization, grouping or weighting of results.

The following table provides a summary of the specific impact categories that were evaluated. In addition, the study also considers Primary Energy Demand, non-renewable (MJ).

Table 3: TRACI Impact Categories

Impact Category	Parameter	Unit (per FU or DU)	Source of the characterization method	Level of site specificity selected	Environmental media
Climate change	Global Warming Potential, GWP	kg CO2 equiv.	TRACI 2.1. July 2012/ IPCC 2007	Global	Air
Acidification	Acidification potential, AP	kg SO2 equiv.	TRACI 2.1. July 2012	North America	Air, Water
Eutrophication	Eutrophication potential, EP	kg N equiv.	TRACI 2.1. July 2012	North America	Air, Water
Smog	Photochemical ozone creation potential, POCP	kg O3 equiv.	TRACI 2.1. July 2012	North America	Air

Important Note: Results presented in this report are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks.

LIFE CYCLE INVENTORY

The life cycle of the artificial tree and real Christmas tree are divided into four distinct and analogous stages:

(1) Manufacturing (artificial Christmas tree) / Cultivation (real Christmas tree)
(2) Finished Tree to Home
(3) Use Phase
(4) End-of-Life Phase

Each of these stages for the artificial and real Christmas tree are described below.

ARTIFICIAL CHRISTMAS TREE METHODOLOGY

MANUFACTURING

The artificial Christmas tree is primarily composed of steel sheets, polyvinylchloride (PVC) and polypropylene (PP). These raw materials go through a series of processing steps that results in an artificial tree and a tree stand.

The main components of an artificial tree are:

(1) Branches
(2) Tree pole
(3) Tree stand and tree top insert
(4) Metal hinge
(5) Metal fastener

The production process of each component is described below. The parts are then assembled for final tree production.

The PVC film produced from PVC resin undergoes cutting and is combined with steel wire to form the tips of the branches. PP yarn produced from PP resin is then attached to the tip of the branches to complete branch assembly.

Steel sheets undergo rolling and cutting processes and are then powder coated using epoxy resin to form the tree pole. The tree stand and tree top insert are made from injection molding PVC resin.

Steel sheets are stamp pressed and powder coated using epoxy resin to form metal hinges. Steel sheets are stamp pressed to produce the metal fastener.

The artificial Christmas tree is packaged in a corrugated cardboard box and sealed using plastic packaging tape.

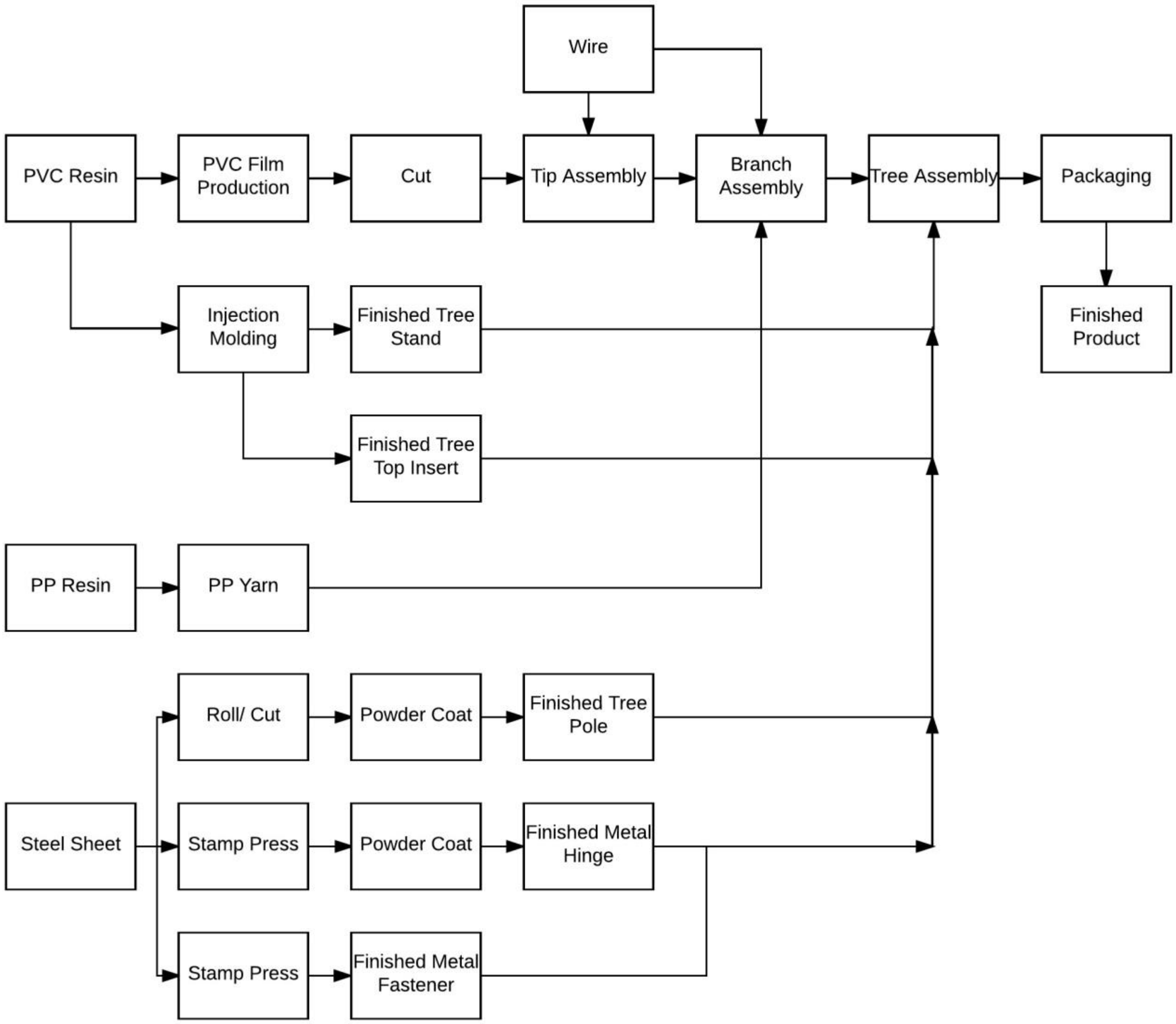


Figure 1: Artificial Tree Manufacturing Flow Diagram

Figure 1 shows the overall manufacturing process of the artificial tree.

Table 4 Inventory of materials for artificial Tree

Component	Input	Amount	Unit
Branches	Polyvinylchloride Resin	1.684	kg
	Stabilizers and Processing Aids	0.2059	kg
	Steel	1.838	kg
	Electricity	0.3063	kWh
	Thermal energy	411.06	Kcal
	Polypropylenne Resin	0.2625	kg
Tree stand and top insert	Polyvinylchloride Resin	0.446	kg
	Electricity	0.0987	kWh
Tree pole	Steel sheets	0.4576	kg
	Electricity	0.1307	kWh
	Thermal energy	81.62	Kcal
	Epoxy resin	0.018	kg
Metal hinge	Steel sheets	0.378	kg
	Electricity	0.0972	kWh
	Thermal energy	45.3	Kcal
	Epoxy resin	0.015	kg
Metal fastener	Steel sheets	0.046	kg
	Electricity	0.0009	kWh
Packaging	Corrugated cardboard	1.4	kg
	Packaging tape	0.03	kg

FINISHED TREE TO HOME

After being manufactured and assembled in China, a truck transports the artificial Christmas tree from the factory to the harbor in China. It is then transported to US port on a container ship, then on a truck from the port to storage facility to retailer. From the retailer, the customer takes the artificial Christmas tree home in a passenger vehicle.

USE

The use phase for an artificial Christmas tree consists of disposal of the cardboard packaging and plastic packaging tape. The tree in the use phase is considered unlit and undecorated; hence, these impacts are not included in the study.

END-OF-LIFE

A worst-case scenario being considered, the artificial Christmas tree at the end of its life is landfilled.

TRANSPORTATION

The transportation distances during production and shipping of the artificial Christmas tree are provided as primary data by ACTA. The distance for truck transport from storage to retailer has been approximated as 1417.83 km (881 miles) (Bureau of Transportation Statistics, 2008). The transport to end-of-life is taken from default values used in EPA's WARM model (U. S. Environmental Protection Agency, 2009). The distance from retailer to end customer is assumed to be 8 km (5 miles). The GaBi database for transportation vehicles was used to model the transportation associated of the artificial Christmas tree. The transportation distances for the artificial tree is summarized in Table 5.

Table 5 Transportation Summary for artificial Tree

Transportation - Artificial Tree		
From - To	Vehicle Type	Distance (One way) (km)
Factory - Harbor (China)	Truck, Euro 3, 20 - 26t gross weight / 17,3t payload capacity	130
Harbor (China) - USA (Port)	Container ship, 27500 dwt payload capacity, ocean going	12023
Port - Storage	Truck - Trailer, basic enclosed / 45,000 lb payload - 8b	25
Storage - Retailer	Truck - Trailer, basic enclosed / 45,000 lb payload - 8b	1418
Retailer to Customer	Grocery transport by car	4
Customer (Cardboard packaging)- End of Life	Truck - Dump Truck / 52,000 lb payload - 8b	161
Customer (Plastic packaging tape)- End of Life	Truck - Dump Truck / 52,000 lb payload - 8b	161
Customer (Artificial Tree)- End of Life	Truck - Dump Truck / 52,000 lb payload - 8b	32

REAL CHRISTMAS TREE METHODOLOGY

The lifetime of a real Christmas tree is its growth phase. The final year of the growth phase is the Christmas season that the tree is harvested for. The growth of the real Christmas tree takes place over an 11-year period that includes 4 years of cultivation of the seedling in a greenhouse and movement of seed for transplant and 7 years of cultivation of the tree in the field. This results in a tree that is 2 m (6.5 ft) and weighs 15 kg at the time of harvest (Konsumo, 2008), (Wahmhoff, n.d.), (Hinesley & Wright , 1989) . The tree density when planted is assumed to be 4000 trees per hectare and when harvested is assumed to be 3500 trees per hectare. Per this assumption, the area occupied by one tree is 2.5 m^2. The real Christmas tree system is described below in detail.

CULTIVATION

The cultivation phase of real Christmas tree life cycle includes the following steps/ activities:

- Planting the seed in nursery;
- Cultivation of seed (years 0-2);
    - Note: In many cases this period can be from 0-3 years. However, this LCA assumes 0-2 years to align with the previous LCA study referenced in this report.
- Transporting the sapling from nursery bed to transplant bed protected by packaging foil using on-farm transport (tractor);
- Cultivation of transplants (years 2-4);
- Transporting the young tree from greenhouse to plantation packaged in a pot using on-farm transport (tractor);
- Planting the transplants in the field;
- Cultivation of tree in the field (years 5-11);
- Real Christmas tree care through cultivation phase;
- Harvesting full grown tree;
- Packaging the tree for transport using polypropylene string.

The tree transported to the retailer also includes the tree stand.

The first two phases of the cultivation phase are modeled using the reforestation dataset (Reforesting, high intensity, US SE) from USLCI. The datasets for reforesting are structured from three general combinations of management intensity and site productivity for each region. For real Christmas tree cultivation purposes, Reforesting, with high intensity in the southeast region was chosen. Since the tree farms are cultivated for commercial trees, it assumed that the management intensity and site productivity would be high. The dataset includes all inputs (including commercial fertilizer, pesticide, electricity at greenhouse, diesel and gasoline for equipment and transport) necessary for cultivation of the young tree from year 0 to year 4 until it is planted in the field at the end of year 4. Subsequently the cultivation phases after the young tree is planted in the field are modeled separately until end-of-life. Inputs to tree during cultivation to harvest in the field were determined (Table 8) as kilograms per hectare per year. These inputs were then converted to the inputs required for the functional unit which is one fully grown real Christmas tree used for one season.

Fuel consumption for initial cultivation (years 0-4) is summarized in Table 2. This represents the background data (Johnson, Lippke, Marshall, & Comnick, 2004) for the “Reforesting” dataset and not the data directly incorporated into the model.

Table 6 Fuel Consumption in initial cultivation (Year 0- Year 4)

Cultivation Step	Fuel Consumption (gal/ac)
Greenhoue & Seedling	5.46
Site Preparation	14.18
Planting	0.71

SEED TO YOUNG TREES:

The seedlings are assumed to be planted by hand. This assumption was made based off of background documentation (Johnson, Lippke, Marshall, & Comnick, 2004). In reality, bigger producers may plant mechanically. They are then transplanted to transplant beds until the end of year four, after which they are moved to the field. When the seedlings are transported to the transplant bed, they are protected using packaging foil. They stay in the field until they are fully grown to be harvested (Years 5-11). According to (NCDA&CS Agricultural Statistics Division, 1996), it was assumed 3,500 out of 4,000 trees are harvested per hectare. This yield factor has been accounted for in the study. Throughout its growth, the tree is pruned annually with hand pruners and shearing knives. As these activities are completed by hand, their impact is not included in this study. At the end of the cultivation period, real Christmas trees are harvested using a chain saw. The chain saw uses 0.002 gallons of gasoline and $3.8x10^{-5}$ gallons of lubricating oil per tree.

FERTILIZATION:

For the reforesting dataset (Years 0-4), the level and type of fertilization is a factor of the region and management intensity. The high intensity option involved fertilization every 4 years. Fertilizer consumption for initial cultivation (Year 0-4) is summarized in Table 7. This represents the background data (Johnson, Lippke, Marshall, & Comnick, 2004) for the "Reforesting" dataset and not the data directly incorporated into the model. The fertilizer mixture included nitrogen, potassium and phosphorous. For the application of fertilizers and pesticides, small tractors were assumed.

Table 7 Fertilizer consumption during initial cultivation (Year 0 – Year 4)

Fertilizer in seedlings	Fertilizer consumption (kg/ha)
Nitrogen	712.86
Phosphate	128.9

For years 5-11, the fertilizers applied are summarized in Table 8. Nitrogen, phosphate, potassium, magnesia sulfate fertilizers and calcium carbonate are applied to the growing tree.

Table 8 Input to real Christmas tree (Year 5 - Year 11)

Input	Amount for 1 tree (5-11 years)	Unit	Source
Ammonium sulfate fertilizer	0.735	kg/tree	Calculated based on (Baumgarten, et al., 2000), (Spectrum Analytic Inc., 2009)
Magnesium sulfate fertilizer	0.104	kg/tree	Calculated based on (Baumgarten, et al., 2000)
Potassium chloride fertilizer	0.578	kg/tree	Calculated based on (Baumgarten, et al., 2000), (Spectrum Analytic Inc., 2009)
Fungicide (Phosphoric acid used as proxy)	0.021	kg/tree	Calculated based on (Kuhns, 2004)
Calcium carbonate fertilizer	0.347	kg/tree	Calculated based on (Baumgarten, et al., 2000)
Diesel for working operations	0.034	l/tree	Calculated

Phosphate fertilizer	1.070	kg/tree	Calculated based on (Baumgarten, et al., 2000), (Spectrum Analytic Inc., 2009)
Herbicide (Glyphosate used as proxy)	0.010	kg/tree	Calculated based on (Kuhns, 2004)
Chemical mower (Glyphosate used as proxy)	0.003	kg/tree	(Hundley & Owen, 2005)

PESTICIDE TREATMENT:

All the input pesticides from year 5-11 are summarized in Table 8. For the application of pesticides, small tractors where assumed in the study.

MOWING:

The real Christmas tree in this model is assumed to be chemically mowed with 26 ounces per acre of 41% glyphosate (Hundley & Owen, 2005) by manual application. Glyphosate is commonly used for the control of perennial plants.

POST-HARVEST TREATMENT AT FARM:

Once the real Christmas tree is harvested, the tree is prepared for transportation to the retailer. Any remaining branches and roots are left undisturbed in the soil.

BALING:

The real Christmas tree is baled using 0.0086 kg of polypropylene string just before it is transported to the retailer.

CARBON UPTAKE DURING CULTIVATION:

Carbon uptake by the tree, is characterized by the amount of CO_2 removed from the atmosphere has been assessed in this study. The carbon uptake is calculated by assuming dry matter content of the whole tree of 40% and the carbon content of dry matter being 49.7%, as shown below

$$kg\ CO_2\ sequestered = 15\ kg\ tree * \frac{40\ kg\ dry\ content}{100\ kg\ tree} * \frac{49.7\ kg\ C}{100\ kg\ dry\ content} * \frac{44.01\ kg\ CO_2}{12.0107\ kg\ C} = 10.927\ kg\ CO_2$$

Carbon losses due to land use change, storage in soil and litter have not been accounted for. Other nutrients such as nitrates and phosphates are assumed to be stored in the soil for the next cultivation phases.

FINISHED TREE TO HOME

The real Christmas tree is transported from farm to retailer on a truck. The twine is assumed to be disposed of at the retailer and then new twine added for the customer to transport the tree home. The customer is assumed to use a regular personal vehicle to bring the tree from the retailer back to his/her home.

USE

The use phase of a real Christmas tree consists of watering the tree for the duration of the Christmas season (assumed to be 18 days). During the use phase, it is assumed that the tree will consume 62 liters of water (Hinesley & Chastagner, 2016), which is the assumed to evaporate to air. The lifespan of the tree stand is 10 years with an average weight of 2.04 kg. The tree stand consists of 90% plastic and 10% steel (FKF 2008, type Cynco C-144).

END-OF-LIFE

All intermediate waste is sent to material specific landfills and all landfill processes have energy recovery from methane production.

The choice of end-of-life for real Christmas tree greatly affects the amount of carbon released and sequestered. This can significantly impact the results. Since the end-of-life for real Christmas tree is not standardized and the trees could be disposed of based on customer preference or municipal programs, different end-of-life scenarios were considered.

For the case of real Christmas tree, three end-of-life scenarios are considered:

(1) Landfilling of Real Christmas tree
(2) Incineration of Real Christmas tree
(3) Composting of Real Christmas tree

End of life impacts are based largely on the chemical composition of the tree. We have assumed no water loss due to evaporation in the use phase and prior to disposal. The datasets in Gabi are assumed to be adjusted to this tree composition. Table 9 summarizes the real Christmas tree composition.

Table 9 Real Christmas tree composition

Variable Description	Value Used
Density of Waste	830 [kg/m3] range: 800-1200, default 1050
Water Content	0.54 [frac] water content of waste
Dry Fraction	0.46 [frac] dry matter of waste
Carbon Content of the Dry Waste	0.526 [kg/kg] C content of waste
Oxygen Content of the Dry Waste	0.406 [kg/kg] O content of waste
Hydrogen Content of the Dry Waste	0.0611 [kg/kg] H content of waste
Nitrogen Content of the Dry Waste	0.0094 [kg/kg] N content of waste

Landfilling of Real Christmas tree:

The estimated distance from the point of disposal to municipal landfill is 32 km (20 miles) (EPA 2009). Landfilling of biomass causes methane emissions. These methane emissions are assumed to be used for electricity generation and they are credited for replacing the electricity supply by US power mix.

Incineration of Real Christmas tree:

It is estimated that the distance from the point of disposal to municipal incineration is 32 km (20 miles) (EPA 2009). The electricity and steam produced from the incinerator, is first used to meet the internal needs of the incinerator and is then returned to the US power grid system and to steam produced by real Christmas gas combustion.

Composting of Real Christmas tree:

It is estimated that the distance from the point of disposal to the composting facility is 32 km (20 miles) (EPA 2009). Total carbon lost during composting is 57.2% of the total weight and total nitrogen lost is 13.9% (EPA 2003). Boldrin et al. determined that 2.7% of the carbon lost is lost as methane and 1.8% of the nitrogen lost is lost as nitrous oxide (Boldrin, Andersen, Moller, Christensen, & Favoino, 2009). It is also estimated that the fraction of carbon sequestered during composting is 0.5, nitrogen loss is 0.005 per kg nitrogen input and the methane to carbon dioxide ratio is 0.1. Using this information and the tree composition information (Energy Research Center of the Netherlands (ECN)) composting was modeled for real Christmas tree disposal. The calculations for composting are as follows:

Weight of the real Christmas tree = 15kg
Dry content of tree = 0.46

<u>Carbon lost as Carbon dioxide (CO_2)</u>

Carbon content of dry waste = 0.526 [kg/kg] C content of waste
Fraction of carbon sequestered during composting = 0.5 (US EPA, 2015)

$$Carbon\ lost = (1 - carbon\ sequestered) * dry\ content\ of\ tree * carbon\ content\ of\ dry\ waste * weight\ of\ tree$$

$$Carbon\ lost = (1 - 0.5) * 0.46 * 0.526 * 14.787 = 1.788\ kg$$

$$Carbon\ lost\ as\ CO2 = carbon\ lost - carbon\ lost\ as\ methane = 1.788 - 0.1625 = 1.6255\ kg$$

$$CO2\ emitted = carbon\ lost\ as\ carbon\ dioxide * \left(\frac{44}{12}\right) = 5.9601\ kg$$

Carbon lost as Methane (CH_4)

Ratio of methane to carbon dioxide = 0.1

$$Carbon\ lost\ as\ CH4 = \frac{methane\ to\ carbon\ dioxide\ ratio * carbon\ lost}{1 + methane\ to\ carbon\ dioxide\ ratio} = \frac{0.1 * 1.788}{1 + 0.1} = 0.1625\ kg$$

$$CH4\ emitted = carbon\ lost\ as\ methane * \left(\frac{16}{12}\right) = 0.2167\ kg$$

Nitrogen lost as Nitrous oxide (N_2O)

Nitrogen content of dry waste = 0.0094 [kg/kg] N content of waste
Nitrogen loss per kg Nitrogen input = 0.005 [kg/kg] nitrogen losses per kg N input

$$Nitrogen\ lost\ during\ degradation = Nitrogen\ input * Nitrogen\ loss * Dry\ Content\ of\ tree * weight\ of\ tree$$

$$Nitrogen\ lost\ during\ degradation = 0.0094 * 0.005 * 0.46 * 14.787 = 0.000319\ kg$$

$$Nitrogen\ lost\ as\ Nitrous\ oxide = Nitrogen\ lost * \left(\frac{44}{12}\right) = 0.00116\ kg$$

No credits were given for fertilizer production.

TRANSPORTATION

Based on data from 2007 transportation distances from the United States Bureau of Transportation Statistics (BTS 2008) and EPA's WARM model, assumptions on the transportation distances were made due to the lack of availability of primary data for the same. All transportation within the farm of the seedlings, tree and other agricultural inputs are done on platform or flatbed trucks. The distances used are summarized in Table 10.

Table 10 Transportation for real Christmas tree

From - To	Distance	Unit
Seed bed to transplant bed	24.1	km
Nursery to plantation	24.1	km
Plantation to farm	3.2	km
Farm to retailer	209.2	km
End customer to retailer and back home	8.0	km
Waste products to landfill	32.2	km
Natural tree to landfill	32.2	km
Natural tree to incineration	32.2	km
Natural tree to composting	32.2	km

Life Cycle Impact Assessment

Results

Environmental Impacts were calculated using the GaBi software platform (version 8). Impact results have been calculated using the EPA's TRACI 2.1 methodology and Primary Energy Demand (Non-renewable) characterization factors. As this study was conducted for a client whose reach extends to North America only, and the cultivation conditions of the real Christmas tree studied were based in the United States, TRACI impact indicators were deemed appropriate for this study. For more information on the background of the TRACI methodology, please visit https://www.epa.gov/chemical-research/tool-reduction-and-assessment-chemicals-and-other-environmental-impacts-traci.

TRACI impact indicators do not have universal international acceptance; however, they are widely used in the United States and are considered to be scientific and technically valid due to being developed and maintained by the United States Environmental Protection Agency (EPA).

Environmental indicators are calculated for the artificial Christmas tree and compared to the real Christmas tree for three different end-of-life scenarios as well as the following three use lifetimes:

(1) 1 year: Assumes that the artificial Christmas tree and real Christmas tree are both used for 1 year before disposal.
(2) 5 years: 1 artificial Christmas tree and 5 real Christmas trees in 5 years.
(3) 10 years: 1 artificial Christmas tree and 10 real Christmas trees in 10 years.

The various environmental metrics analyzed are: Primary Energy Demand from Non-renewable sources, Acidification Potential, Eutrophication Potential, Global Warming Potential and Smog Potential. The metrics are summarized in Table 11 for the 1-year scenario for both artificial and real Christmas trees.

The TRACI impact categories of human health impacts and ecotoxicity were not included for this study. Both of these indicators are highly sensitive to small amounts of chemicals (such as those used for herbicides) within the model. As available GaBi databases were used as proxies to represent the chemicals used in the cultivation of the natural tree, the results of these impact categories were deemed to be more inaccurate than the environmental impact categories and therefore were not included. Furthermore, land use change within TRACI was considered but as the datasets within the model did not properly take into account the land use change of the natural tree usage, the results were not included.

Table 11 Life cycle impacts of an artificial and real Christmas tree used for a one year use scenario

impact Category	Unit	Artificial Tree Full LCA	Natural Tree Full LCA		
			Composting	Incineration	Landfill
Primary Energy Demand (PED) Non renewable	MJ	284.000	101.503	-97.182	106.888
Acidification Potential (AP)	kg SO2-Equiv.	0.088	0.026	0.007	0.076
Eutrophication Potential (EP)	kg N-Equiv.	0.006	0.015	0.014	0.041
Global Warming Potential (GWP)	kg CO2-Equiv.	17.911	4.875	7.775	-0.105
Smog Potential	kg O3-Equiv.	1.500	0.332	0.099	0.439

Table 12 GWP of artificial Tree vs. real Christmas tree by Life cycle stage

			Total	Manufacturing /Cultivation	Transport	Use	End of Life
Global Warming Potential (kg CO2-Equiv.)	Artificial Tree	Artificial Tree	17.911	14.200	2.410	1.070	0.231
	Natural Tree 1 year	Composting	4.875	-9.010	1.800	0.076	12.010
		Incineration	7.775	-9.010	1.800	0.076	14.910
		Landfill	-0.105	-9.010	1.800	0.076	7.030
	Natural Tree 5 years	Composting	24.377	-45.050	9.000	0.379	60.048
		Incineration	38.877	-45.050	9.000	0.379	74.548
		Landfill	-0.523	-45.050	9.000	0.379	35.148
	Natural Tree 10 years	Composting	48.754	-90.100	18.000	0.758	120.096
		Incineration	77.754	-90.100	18.000	0.758	149.096
		Landfill	-1.046	-90.100	18.000	0.758	70.296

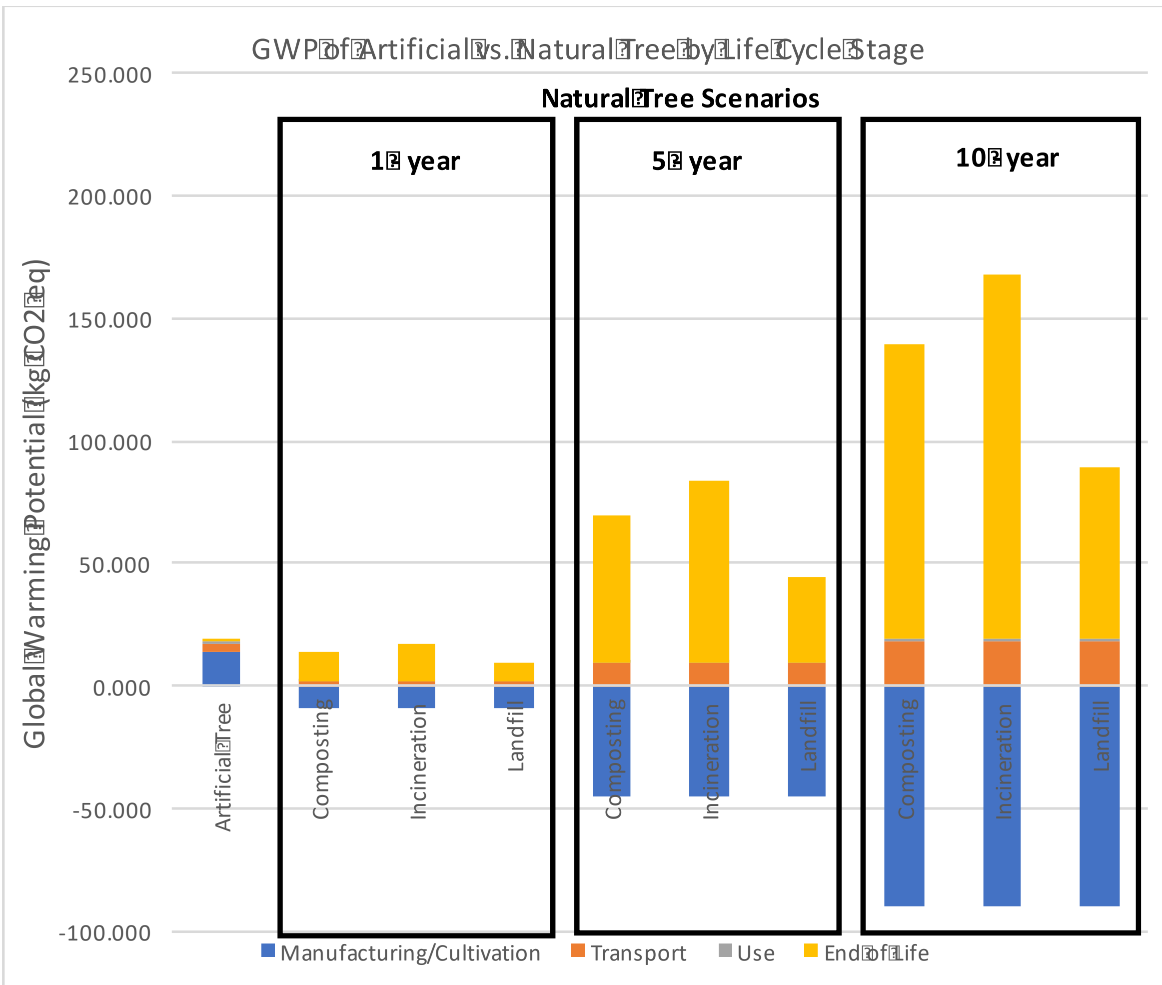


Figure 2: GWP of artificial Trees vs. real Christmas tree

Global Warming Potential is a measure of greenhouse gas emissions such as carbon dioxide and methane. Here it is measured as kg CO_2 equivalent. Greenhouse gases are important to measure and reduce as they warm the Earth by absorbing energy and slow the rate of energy escaping into space. This is one of the main causes of climate change. The Global Warming Potential (GWP) for the artificial Christmas tree vs. the real Christmas tree is shown in Figure 2 and Table 12. Overall, the GWP for artificial Christmas tree is higher than the real Christmas tree in all three scenarios. The biggest contributor to GWP in the artificial Christmas tree is manufacturing (80%). Among the real Christmas tree scenarios, landfilling has the least GWP, followed by composting and incineration. Transportation accounts to around 15% of total GWP for the artificial Christmas tree and 10-12% for real Christmas tree. The use phase contribution to GWP for the artificial Christmas tree is around 7% mainly attributed to the disposal of packaging at the end of use phase.

The various end-of-life scenarios release different amounts of carbon into the air and in different forms. The amount of carbon not released at end-of-life remains sequestered as biomass (for real Christmas trees). Hence, the end-of-life that releases the least amount of carbon has the least GWP, which in this case is landfilling (40% of total GWP). This could be attributed to the fact that landfilling receives credit for electricity produced from the captured landfill gases.

The GWP for end-of-life (landfilling) for artificial Christmas tree appears to be minimal, but one must remember that the artificial Christmas tree is made out of plastic and steel that does not decompose and hence does not release any carbon dioxide or methane. However, these occupy space on landfills if they are not recycled and reused. So, from the GWP perspective, real Christmas trees seem to have a greater GWP than artificial Christmas trees, but the above perspective must be kept in mind when analyzing the better option.

Apart from the above results, a further break-even analysis was done to compare how long the artificial Christmas tree would need to be used before disposing so that it is as equal to the real Christmas tree in terms of GWP. While viewing these results, one must remember that, a breakeven analysis and comparison for negative number is not possible and hence the break-even point for a landfilled real Christmas tree is not included here. In the case that the real Christmas tree is composted, the break-even point is 4 years, which means that the artificial Christmas tree will need to be used for 4 Christmas seasons before it is equal to a real Christmas tree that is composted at its end-of-life, from the Global Warming standpoint. In the case of the real Christmas tree being incinerated, the artificial Christmas tree must be used for at least 3 years before its GWP is less than the real Christmas tree.

Table 13 PED (Non-renewable) of artificial Tree vs. real Christmas tree by Life cycle stage

			Total	Manufacturing /Cultivation	Transport	Use	End of Life
Primary Energy Demand (PED) Non renewable (MJ)	Artificial Tree	Artificial Tree	284.000	247.000	32.500	0.532	3.670
	Natural Tree 1 year	Composting	101.503	75.700	24.300	0.665	0.838
		Incineration	-97.182	75.700	24.300	0.665	-197.847
		Landfill	106.888	75.700	24.300	0.665	6.223
	Natural Tree 5 years	Composting	507.515	378.500	121.500	3.325	4.190
		Incineration	-485.910	378.500	121.500	3.325	-989.235
		Landfill	534.440	378.500	121.500	3.325	31.115
	Natural Tree 10 years	Composting	1015.030	757.000	243.000	6.650	8.380
		Incineration	-971.820	757.000	243.000	6.650	-1978.470
		Landfill	1068.880	757.000	243.000	6.650	62.230

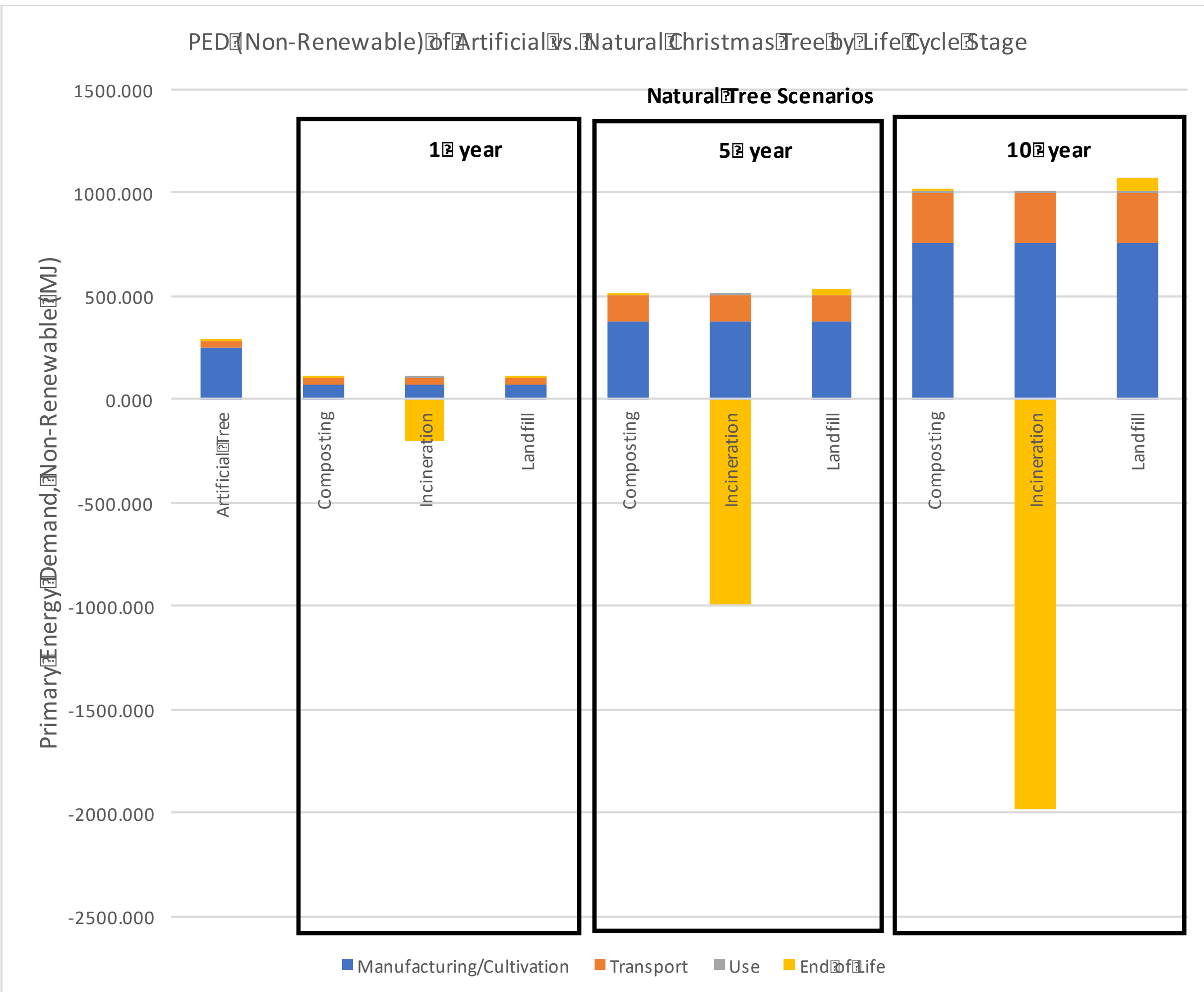


Figure 3: PED (non-renewable) of artificial Tree Vs. real Christmas tree

Primary Energy Demand (PED) is the total amount of primary energy associated with the product. It includes the total amount of energy used during the product lifecycle plus the amount of energy that the product would release upon combustion. The energy tabulated in Table 13 is from non-renewable sources such as petroleum and natural gas.

The non-renewable PED for real Christmas tree is mainly associated with cultivation (28% - 75%) (Figure 3). Among the three end-of-life scenarios, incineration has the least PED in the cultivation stage and negative PED overall. This can be attributed to the fact that incineration receives energy credits for electricity and steam produced from combustion. The other contributor to PED for real Christmas trees is transport (20%). Even though landfilling also receives credits for energy recovered from the emissions released from the landfill, the operation of the landfill outweighs the electricity produced from the landfill. In the composting scenario, the PED is attributed to cultivation (75%) and transportation (22%).

The non-renewable PED for the artificial Christmas tree is mainly associated with manufacturing (87%), followed by transport (11%). The manufacturing process for artificial Christmas tree is energy intensive as it involves processing and assembling steel and plastic.

The break-even point for PED (non-renewable) is 3 years for both the landfilling and composting scenarios. This means that the artificial Christmas tree must be used for at least 3 years before its PED is equal to the real Christmas tree when composted or landfilled. The incineration break-even point is not included as the calculated impacts are a negative number due to the energy credits from the waste-to-energy process.

Acidification Potential

Table 14 Acidification Potential of artificial Tree vs. real Christmas tree by Life cycle stage

			Total	Manufacturing /Cultivation	Transport	Use	End of Life
Acidification Potential (AP) (kg SO2-Equiv.)	Artificial Tree	Artificial Tree	8.83E-02	4.33E-02	3.90E-02	3.63E-03	2.39E-03
	Natural Tree 1 year	Composting	2.65E-02	2.31E-02	2.81E-03	1.95E-04	3.47E-04
		Incineration	6.54E-03	2.31E-02	2.81E-03	1.95E-04	-1.96E-02
		Landfill	7.59E-02	2.31E-02	2.81E-03	1.95E-04	4.98E-02
	Natural Tree 5 years	Composting	1.32E-01	1.16E-01	1.41E-02	9.75E-04	1.74E-03
		Incineration	3.27E-02	1.16E-01	1.41E-02	9.75E-04	-9.78E-02
		Landfill	3.80E-01	1.16E-01	1.41E-02	9.75E-04	2.49E-01
	Natural Tree 10 years	Composting	2.65E-01	2.31E-01	2.81E-02	1.95E-03	3.47E-03
		Incineration	6.54E-02	2.31E-01	2.81E-02	1.95E-03	-1.96E-01
		Landfill	7.59E-01	2.31E-01	2.81E-02	1.95E-03	4.98E-01

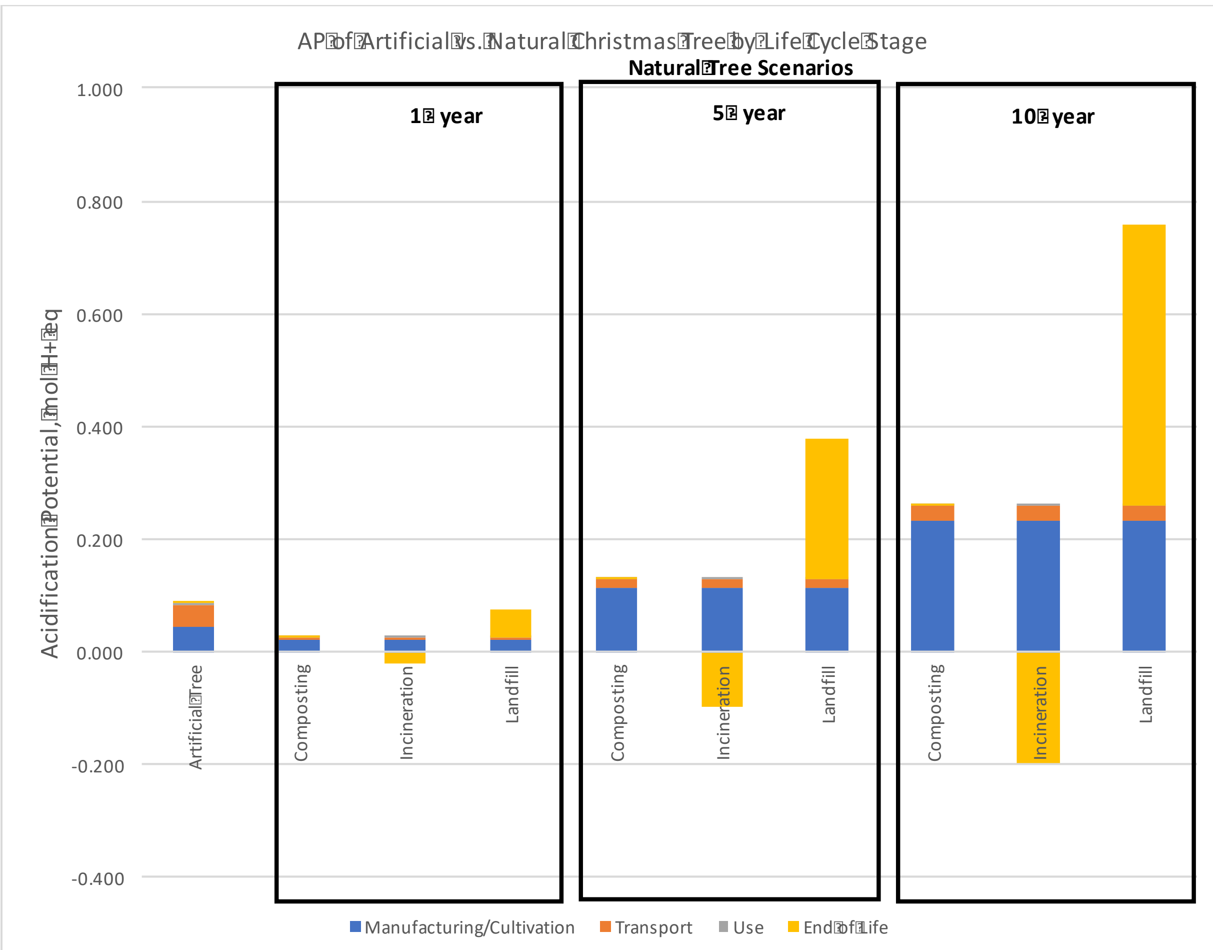


Figure 4: Acidification Potential of artificial Tree Vs. real Christmas tree

Acidification potential (AP) measures the emissions that cause acidifying effects to the environment i.e. acid rain. Sulfur dioxide and nitrogen oxides are primary causes for acid rain as the combine with free halogen atoms to form sulfuric and nitric acid. This eventually leads to acidity of soil and water resources. They are also harmful to buildings and other man-made structures as they aid in corrosion. The AP of both trees are summarized in Table 14 and Figure 4.

For artificial Christmas trees, about 50% of the AP is due to manufacturing. Transportation causes about 40% of the total AP over its lifetime. The contribution of use phase and end-of-life are minimal to AP. Again, one must keep in mind that this could be because landfilling of steel and plastic does not lead directly to large scale releases of acidification causing chemicals, but its production does, as we see in this case. The production of the artificial Christmas tree is energy intensive and use of electricity during manufacturing is a major cause of sulfur dioxide and nitrogen oxide emissions. This is one of the main contributors to high (almost 50%) AP from the manufacturing phase.

For real Christmas tree, cultivation has largest AP, ranging between 40% to 83% depending on the end-of-life scenario. The acidification impact of landfilling the tree is 42% of the total AP of the landfilled tree. This can be attributed to the fact that any leachate that escapes the landfill could potentially contaminate ground water and soil. The high AP can also be due to the fossil fuels burned in order to operate the landfill. The AP of the incineration of real Christmas tree scenario is 52% of the total AP of the incinerated tree. This is mainly due to the operation of the incineration facility. However, it is offset by the electricity and steam produced at the facility. The AP of the composting scenario is very small compared to the other scenarios, around 3%. Transportation contributes to around 7-13% of overall AP.

The break-even point for AP in the composting of real Christmas tree scenario is 4. This means that the artificial Christmas tree must be used for at least 4 years before it’s AP is less than the real Christmas tree in terms of Acidification Potential. For the case that the real Christmas tree is landfilled, the artificial Christmas tree must be used for 2 years before disposal. Due to the energy credits from the waste-to-energy process for the incineration scenario, the break-even point in this case is 14 years.

EUTROPHICATION POTENTIAL

Table 15 Eutrophication Potential of artificial Tree vs. real Christmas tree by Life cycle stage

			Total	Manufacturing /Cultivation	Transport	Use	End of Life
Eutrophication Potential (EP) (kg N-Equiv.)	Artificial Tree	Artificial Tree	6.06E-03	2.96E-03	1.61E-03	7.67E-04	7.26E-04
	Natural Tree – 1 year	Composting	1.47E-02	1.40E-02	5.29E-04	8.81E-05	6.71E-05
		Incineration	1.39E-02	1.40E-02	5.29E-04	8.81E-05	-7.59E-04
		Landfill	4.09E-02	1.40E-02	5.29E-04	8.81E-05	2.62E-02
	Natural Tree – 5 years	Composting	7.34E-02	7.00E-02	2.65E-03	4.41E-04	3.36E-04
		Incineration	6.93E-02	7.00E-02	2.65E-03	4.41E-04	-3.79E-03
		Landfill	2.04E-01	7.00E-02	2.65E-03	4.41E-04	1.31E-01
	Natural Tree – 10 years	Composting	1.47E-01	1.40E-01	5.29E-03	8.81E-04	6.71E-04
		Incineration	1.39E-01	1.40E-01	5.29E-03	8.81E-04	-7.59E-03
		Landfill	4.09E-01	1.40E-01	5.29E-03	8.81E-04	2.62E-01

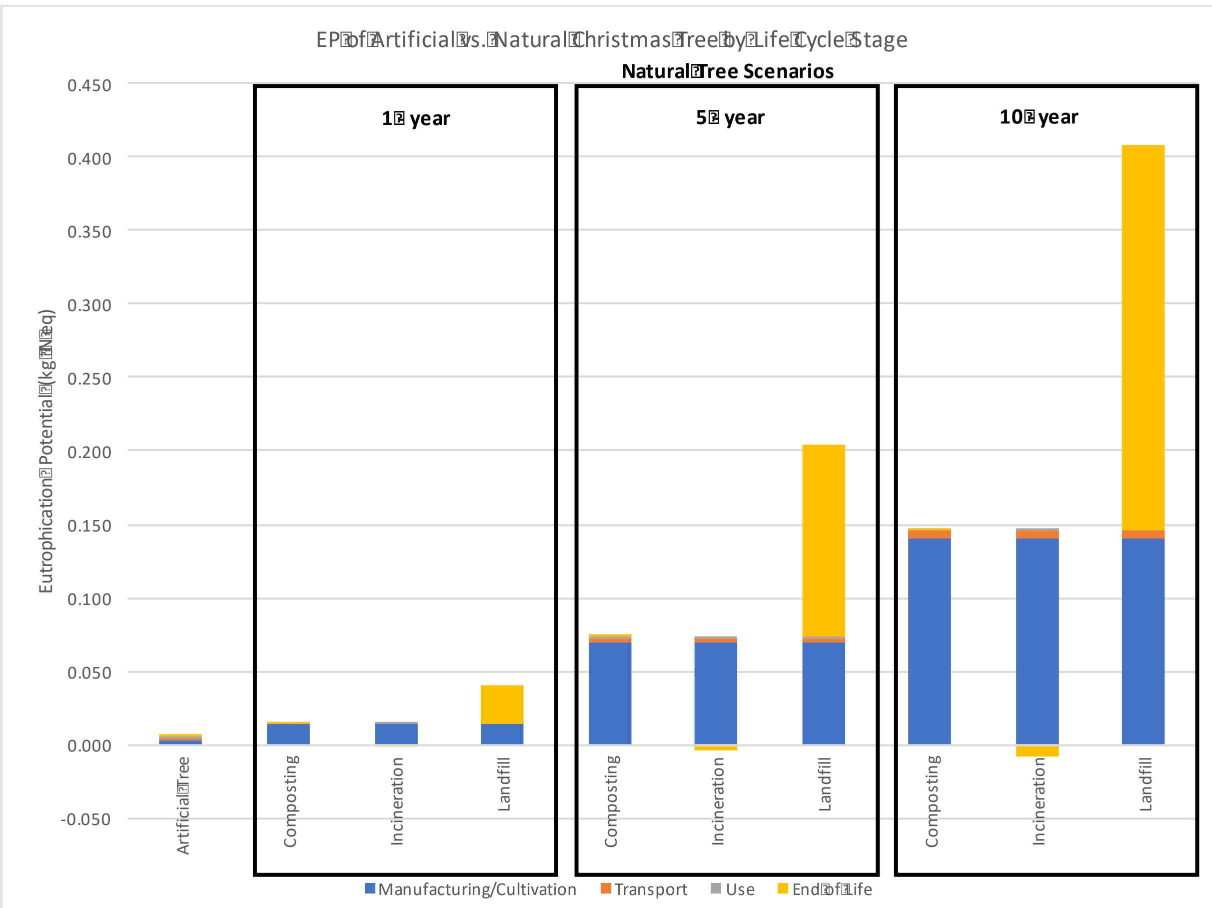


Figure 5: Eutrophication Potential of artificial Tree vs. real Christmas tree

Overall the landfilled real Christmas tree scenario has the largest Eutrophication Potential (EP). EP is the nutrient enrichment in water or soil and can be measured in terms of nitrogen or phosphorous. It causes excessive biomass growth and decay in water and soil, resulting in oxygen depletion. Here it is measured as the amount of nitrogen equivalent.

The EP associated with manufacturing is highest (43%) in the artificial Christmas tree scenario. This is followed by transportation which is 40% of the total EP of the artificial Christmas tree. This transport is mainly associated with the trucking and shipping of the artificial Christmas tree from the factory in China to the retailer in USA. End of life and use phase contribute 7% and 9% respectively to overall EP of the artificial Christmas tree.

The EP associated with cultivation of the real Christmas tree ranges between 4% and 53%. In the landfilling of real Christmas tree scenario, majority of the eutrophication impact is from the landfilling stage, but cultivation contributed to only 4% of the overall EP. This is because during the cultivation phase, the tree acts as a sink of nitrogen. But, during landfilling, the leachate that escapes the landfill contaminates the nearby soil and water sources. Even electricity credit from the landfill does not offset the overall EP. In the case of incineration, cultivation has the largest EP. EP for end-of-life is around 35% of the overall EP of real Christmas tree, mainly due to the energy and steam credit given for the electricity and steam produced during incineration. However, this is not enough to offset the total eutrophication impacts from the other life cycle stages. Cultivation is again the highest contributor to the composted real Christmas tree at 54%. Composting is around 17% of the overall EP of the real Christmas tree scenario. This could be mainly because during composting, only 13.9% of the nitrogen in the tree is lost, then rest gets sequestered in compost thus becoming a nitrogen rich fertilizer that can be used to enrich soil nutrients.

Table 16 Smog Potential of artificial Tree vs. real Christmas tree by Life cycle stage

			Total	Manufacturing /Cultivation	Transport	Use	End of Life
Smog Potential (kg O3-Equiv.)	Artificial Tree	Artificial Tree	1.50E+00	6.86E-01	7.71E-01	1.69E-02	2.65E-02
	Natural Tree 1 year	Composting	3.32E-01	2.42E-01	7.62E-02	2.13E-03	1.14E-02
		Incineration	9.86E-02	2.42E-01	7.62E-02	2.13E-03	-2.22E-01
		Landfill	4.39E-01	2.42E-01	7.62E-02	2.13E-03	1.18E-01
	Natural Tree 5 years	Composting	1.66E+00	1.21E+00	3.81E-01	1.07E-02	5.68E-02
		Incineration	4.93E-01	1.21E+00	3.81E-01	1.07E-02	-1.11E+00
		Landfill	2.19E+00	1.21E+00	3.81E-01	1.07E-02	5.91E-01
	Natural Tree 10 years	Composting	3.32E+00	2.42E+00	7.62E-01	2.13E-02	1.14E-01
		Incineration	9.86E-01	2.42E+00	7.62E-01	2.13E-02	-2.22E+00
		Landfill	4.39E+00	2.42E+00	7.62E-01	2.13E-02	1.18E+00

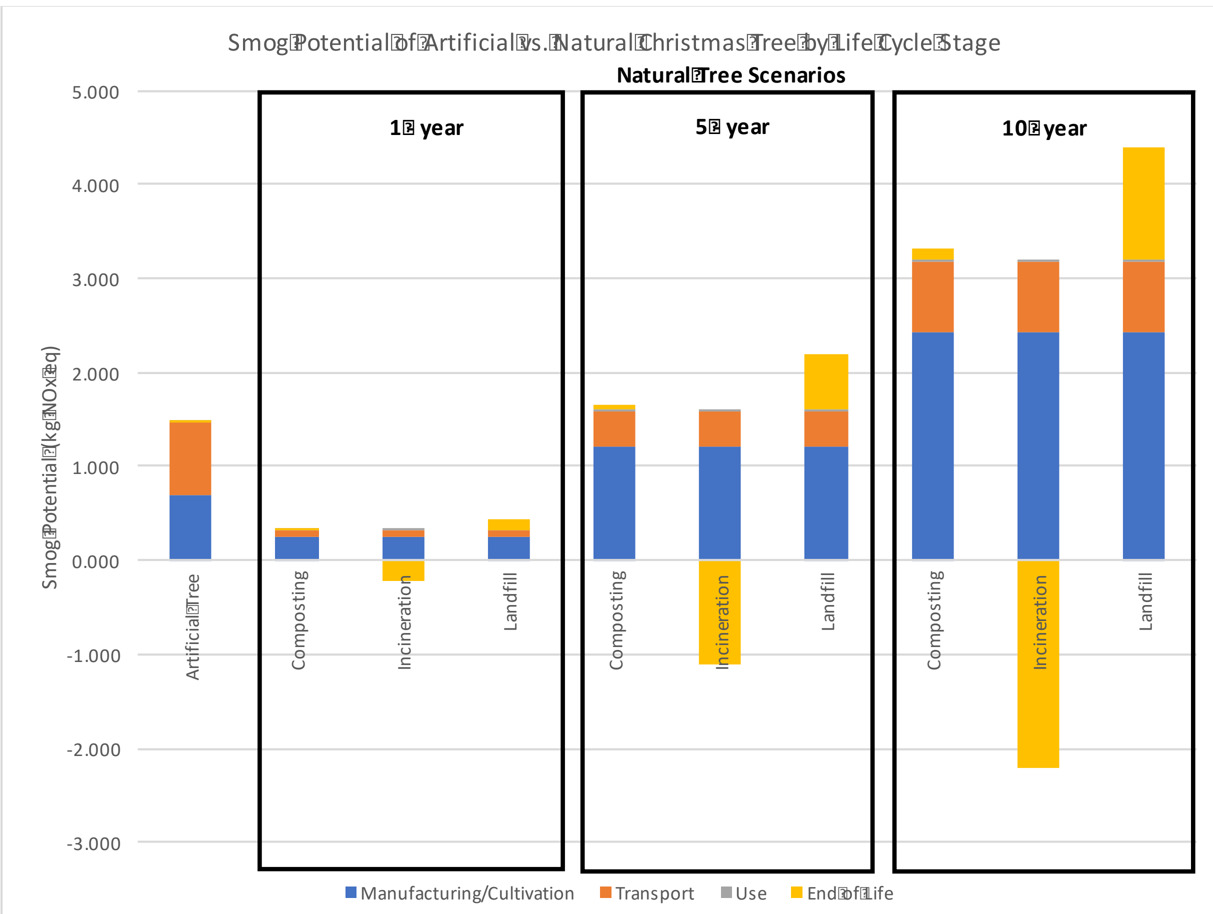


Figure 6: Smog Potential of artificial Tree Vs. real Christmas tree

Smog is essentially a mixture of smoke and fog. It occurs purely due to air pollution caused by fuels being burnt. Smog mainly consists of ground level ozone, water vapor and fine particles. Ground level ozone and fine particles are released into the air due to photochemical reactions between VOCs, Sulphur dioxides and nitrogen oxides. Here, smog potential (SP) is measured as kg of ozone equivalent.

Overall among the two tree models, artificial Christmas tree has the highest smog potential. Among the life cycle stages of both the tree models, manufacturing/ cultivation and transportation have the highest SP. This can be attributed to the fact that manufacturing uses electricity from burning fossil fuels and cultivation and transportation uses diesel and gasoline which is also obtained from fossil fuels. Thus, they contribute immensely to SP.

In the artificial Christmas tree, use and end-of-life contributes only 3% of overall SP over its entire life cycle. Shipping the product from China to the USA is an important contributor to the high SP in the transportation phase.

In the real Christmas tree case, landfilling has the highest SP even though it receives credit for electricity generation, the operational energy for the landfill outweighs the credits that it receives. The composting process releases only 1.8% of nitrogen oxides into the air (Boldrin, Andersen, Moller, Christensen, & Favoino, 2009) thus having less of an impact on SP. Incineration of the real Christmas tree however, receives credit due to electricity and steam production that is enough to offset the energy used in the incineration process.

The break-even point for the composting scenario is 5 years. In other words, the artificial Christmas tree will have to be used for 5 years for its smog creation potential to be lower than that of the real Christmas tree which is composted at the end of its life. Similarly, the artificial Christmas tree will have to be reused 16 times for its smog potential to be lower than the real Christmas tree that is incinerated. As mentioned above, this is mainly due to the energy credits that the incineration process receives. The artificial Christmas tree will have to be used for 4 years so that its SP is lower than the real Christmas tree option.

WATER USAGE

Table 16 Water Usage of artificial Tree vs. real Christmas tree by Life cycle stage

			Total	Manufacturing /Cultivation	Transport	Use	End of Life
Water Usage (m3)	Artificial Tree	Artificial Tree	1.42E-01	1.35E-01	4.62E-03	-1.05E-05	2.73E-03
	Natural Tree 1 year	Composting	1.21E-01	4.14E-02	5.45E-03	7.36E-02	2.40E-04
		Incineration	7.30E-02	4.14E-02	5.45E-03	7.36E-02	-4.75E-02
		Landfill	1.23E-01	4.14E-02	5.45E-03	7.36E-02	2.95E-03
	Natural Tree 5 years	Composting	6.03E-01	2.07E-01	2.73E-02	3.68E-01	1.20E-03
		Incineration	3.65E-01	2.07E-01	2.73E-02	3.68E-01	-2.37E-01
		Landfill	6.17E-01	2.07E-01	2.73E-02	3.68E-01	1.48E-02
	Natural Tree 10 years	Composting	1.21E+00	4.14E-01	5.45E-02	7.36E-01	2.40E-03
		Incineration	7.30E-01	4.14E-01	5.45E-02	7.36E-01	-4.75E-01
		Landfill	1.23E+00	4.14E-01	5.45E-02	7.36E-01	2.95E-02

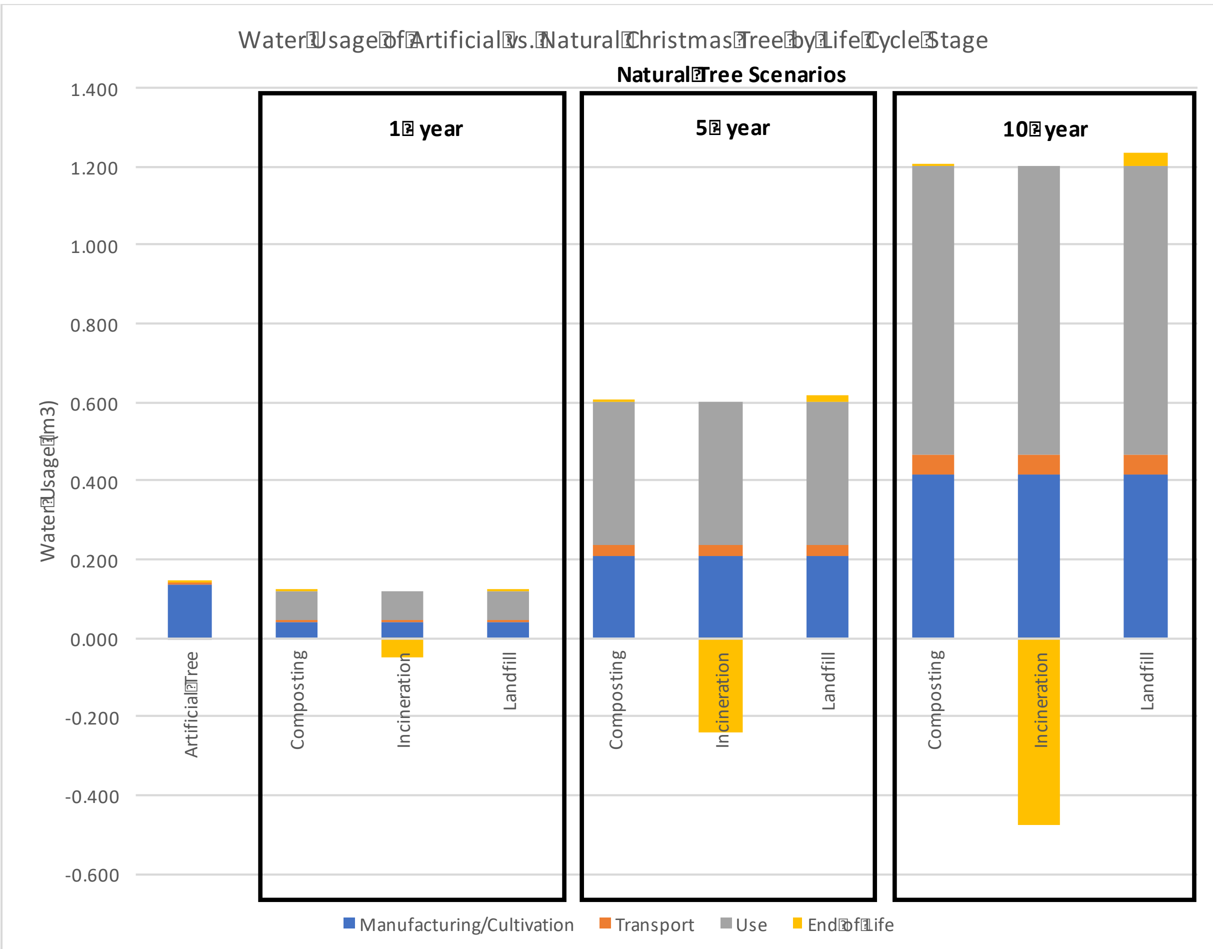


Figure 7: Water Usage of artificial Tree Vs. real Christmas tree

While water usage was not one of the initial impact categories chosen as part of scope of the study, it was included based on the recommendation of the review panel.

Overall, one artificial Christmas tree uses more water over the whole life cycle than one natural tree. The artificial Christmas tree has the majority of the water usage coming from the upstream raw material creation. The natural tree on the other hand has the majority of the water usage in the use phase from keeping the tree hydrated in the house. Further details on the water used during the phase are described on page 17.

Irrigation of the plant from 0-4 years (Seed to young tree phase). Once the tree is transplanted into the field at year 5, it is assumed the tree gets its water from natural rainfall. The results for water are sensitive to this assumption, however, variability in irrigation practices and primary data make it difficult to accurately estimate water use in the period that the tree is transplanted in the field.

Based on the amount of water utilized in both scenarios, an artificial Christmas tree would use less water than the natural tree option after two Christmas seasons.

INTERPRETATION

TRANSPARENCY IN TERMS OF VALUE CHOICE, RATIONALES AND EXPERT JUDGMENTS THAT MAY HAVE AFFECTED THE LCA.

Several value choices and judgements are present that might have affected the results of the LCA:

- The choice of proxies for the cultivation of real Christmas tree
- The carbon uptake of real Christmas tree during cultivation
- Composting process for real Christmas tree
- Proxies for raw materials for artificial Christmas tree
- Exclusion/ Inclusion of credits in the end-of-life for real Christmas tree could change the results, especially for incineration

Details on the above have been addressed in the report and the data quality analysis and sensitivity analysis below.

SENSITIVITY ANALYSIS

The model is sensitive to the following assumptions and data:

- **Data and model of cultivation:** Availability of primary data or a single dataset to model the tree's entire growth cycle would have been ideal but was not available. Despite these constraints, we have modeled the tree's growth in two phases (years 0-4 and 5-11). Using primary data might adjust some of the results as cultivation has a huge overall impact in the real Christmas tree's life cycle.
- **Carbon uptake during cultivation:** The data for carbon uptake was obtained from literature and calculations were derived from there. Since trees act as a major carbon sink during cultivation, any differences in this value could affect GWP in the LCA results.
- **End of life scenario for real Christmas tree:** As seen from the results above, impacts of end-of-life scenarios vary greatly from each other. Inclusion and/ or exclusion of credits from these end-of-life scenarios also affects conclusions from the LCA. Three different end-of-life scenarios have been chosen due to uncertainty in the method of disposal of real Christmas tree in literature and practice.
- **Type of landfill for real Christmas tree:** Selection of different datasets for landfilling of real Christmas tree produced variability in the results.
- **Transportation distances for real Christmas tree:** Due to the unavailability of primary data, conservative estimates were made by referring to US EPA and WARM datasets.

DATA QUALITY ANALYSIS

Overall, the data quality is considered to be good, but the availability of primary data in both cases would be ideal for an accurate assessment. Table 2 lists all the dataset references used in the model. The data for the artificial Christmas tree is excellent as it is primary data supplied directly from ACTA. However, for some of the raw materials commercial datasets in the modeling software were not available, hence appropriate proxies were used. All the energy and waste data provided was process specific and this can be considered accurate.

The data for real Christmas tree was based on literature, derived calculations and a few assumptions. The assessment would be more accurate in the presence of primary data, specifically for cultivation. Due to the unavailability of a single dataset to model the entire growth phase of the tree, we modeled it separately as two different stages over the cultivation phase. For some inputs over the cultivation phase, data from literature was harnessed and used in the model. Whenever possible, the exact dataset was used and in other cases, the closest estimate was used. Another area where we encountered lack of primary data and appropriate proxies was the composting phase in the real Christmas tree (one of the three end-of-life scenarios). For this, a new model was created using data from literature and derived calculations.

CONCLUSIONS

Summary: Main Contributors to Impacts – artificial Christmas tree and real Christmas tree

Overall for the artificial tree, manufacturing seems to be the main contributor to majority of the impact indictors. From the global warming standpoint, manufacturing is the largest contributor for the artificial tree and end-of-life methods is the largest contributor for the real Christmas tree. For all the other indicators, cultivation is the largest contributor for the real Christmas tree.

Trends Across Life Cycle Stages

Table 17 summarizes all the impacts for both artificial Christmas and real Christmas tree over various stages of its life cycle. A red cell indicates the highest impacts in a category. Green indicates the lowest impacts. From this table, we can understand trends across various impact categories. In general, the manufacturing phase of the artificial Christmas tree and the cultivation phase of the real Christmas tree produce the majority of the impacts across all categories. The one exception to this trend is that the end-of-life phase of the real Christmas tree results in the largest GHG impact in the real Christmas tree’s life cycle. This difference is, in part due, to modeling decisions concerning the handling of carbon sequestration in the cultivation phase and carbon release in the end-of-life stage.

Table 17 Combined overall summary of impacts

- A red cell indicates the highest impacts in a category. Green indicates the lowest impacts.

	Time period	EOL Scenerio	Total	Manufacturing /Cultivation	Transport	Use	End of Life
			Artificial Tree				
Global Warming Potential (kg CO2-Equiv.)			17.911	14.200	2.410	1.070	0.231
Primary Energy Demand (PED) Non renwable (MJ)			284.000	247.000	32.500	0.532	3.670
Acidification Potential (AP) (kg SO2 Equiv.)			8.83E-02	4.33E-02	3.90E-02	3.63E-03	2.39E-03
Eutrophication Potential (EP) (kg N-Equiv.)			6.06E-03	2.96E-03	1.61E-03	7.67E-04	7.26E-04
Smog Potential (kg O3-Equiv.)			1.50E+00	6.86E-01	7.71E-01	1.69E-02	2.65E-02
	Time period	EOL Scenerio	Real Tree				
Global Warming	1 year	Composting	4.875	-9.010	1.800	0.076	12.010
		Incineration	7.775	-9.010	1.800	0.076	14.910
		Landfill	-0.105	-9.010	1.800	0.076	7.030
	5 year	Composting	24.377	-45.050	9.000	0.379	60.048
		Incineration	38.877	-45.050	9.000	0.379	74.548
		Landfill	-0.523	-45.050	9.000	0.379	35.148
	10 year	Composting	48.754	-90.100	18.000	0.758	120.096
		Incineration	77.754	-90.100	18.000	0.758	149.096
		Landfill	-1.046	-90.100	18.000	0.758	70.296
Primary Energy Demand	1 year	Composting	101.503	75.700	24.300	0.665	0.838
		Incineration	-97.182	75.700	24.300	0.665	-197.847
		Landfill	106.888	75.700	24.300	0.665	6.223
	5 year	Composting	507.515	378.500	121.500	3.325	4.190
		Incineration	-485.910	378.500	121.500	3.325	-989.235
		Landfill	534.440	378.500	121.500	3.325	31.115
	10 year	Composting	1015.030	757.000	243.000	6.650	8.380
		Incineration	-971.820	757.000	243.000	6.650	-1978.470
		Landfill	1068.880	757.000	243.000	6.650	62.230
Acidification	1 year	Composting	8.83E-02	4.33E-02	3.90E-02	3.63E-03	2.39E-03
		Incineration	2.65E-02	2.31E-02	2.81E-03	1.95E-04	3.47E-04
		Landfill	6.54E-03	2.31E-02	2.81E-03	1.95E-04	-1.96E-02
	5 year	Composting	7.59E-02	2.31E-02	2.81E-03	1.95E-04	4.98E-02
		Incineration	1.32E-01	1.16E-01	1.41E-02	9.75E-04	1.74E-03
		Landfill	3.27E-02	1.16E-01	1.41E-02	9.75E-04	-9.78E-02
	10 year	Composting	3.80E-01	1.16E-01	1.41E-02	9.75E-04	2.49E-01
		Incineration	2.65E-01	2.31E-01	2.81E-02	1.95E-03	3.47E-03
		Landfill	6.54E-02	2.31E-01	2.81E-02	1.95E-03	-1.96E-01
Eutrophication	1 year	Composting	1.47E-02	1.40E-02	5.29E-04	8.81E-05	6.71E-05
		Incineration	1.39E-02	1.40E-02	5.29E-04	8.81E-05	-7.59E-04
		Landfill	4.09E-02	1.40E-02	5.29E-04	8.81E-05	2.62E-02
	5 year	Composting	7.34E-02	7.00E-02	2.65E-03	4.41E-04	3.36E-04
		Incineration	6.93E-02	7.00E-02	2.65E-03	4.41E-04	-3.79E-03
		Landfill	2.04E-01	7.00E-02	2.65E-03	4.41E-04	1.31E-01
	10 year	Composting	1.47E-01	1.40E-01	5.29E-03	8.81E-04	6.71E-04
		Incineration	1.39E-01	1.40E-01	5.29E-03	8.81E-04	-7.59E-03
		Landfill	4.09E-01	1.40E-01	5.29E-03	8.81E-04	2.62E-01
Smog	1 year	Composting	3.32E-01	2.42E-01	7.62E-02	2.13E-03	1.14E-02
		Incineration	9.86E-02	2.42E-01	7.62E-02	2.13E-03	-2.22E-01
		Landfill	4.39E-01	2.42E-01	7.62E-02	2.13E-03	1.18E-01
	5 year	Composting	1.66E+00	1.21E+00	3.81E-01	1.07E-02	5.68E-02
		Incineration	4.93E-01	1.21E+00	3.81E-01	1.07E-02	-1.11E+00
		Landfill	2.19E+00	1.21E+00	3.81E-01	1.07E-02	5.91E-01
	10 year	Composting	3.32E+00	2.42E+00	7.62E-01	2.13E-02	1.14E-01
		Incineration	9.86E-01	2.42E+00	7.62E-01	2.13E-02	-2.22E+00
		Landfill	4.39E+00	2.42E+00	7.62E-01	2.13E-02	1.18E+00

Impacts Associated with artificial Christmas tree Raw Materials

Table 18 Impact of raw materials for artificial tree

Component	Input	Amount	Unit	% Weight	% of GHG Impact*	Impact Factor** GHG	% of AP Impact*	Impact Factor** AP	% of EP Impact*	Impact Factor** EP	% of Smog Impact*	Impact Factor** Smog	% of ADP Fossil Impact*	Impact Factor** ADP Fossil
Branches	Polyvinylchloride Resin	1.68	kg	25%	25%	0.99	11%	0.42	8%	0.33	11%	0.46	36%	1.45
	Stabilizers and Processing Aids	0.21	kg	3%	3%	0.92	1%	0.43	4%	1.42	2%	0.49	5%	1.58
	Steel	1.84	kg	27%	18%	0.68	10%	0.36	5%	0.18	8%	0.28	13%	0.48
	Polypropylenne Resin	0.26	kg	4%	3%	0.85	1%	0.31	35%	9.04	2%	0.39	7%	1.86
Tree stand and top insert	Polyvinylchloride Resin	0.45	kg	7%	7%	0.99	3%	0.43	2%	0.33	3%	0.46	10%	1.44
Tree pole, Metal Hinge and Metal Fastener	Steel sheets	0.88	kg	13%	3%	0.25	7%	0.57	5%	0.36	7%	0.50	8%	0.62
	Epoxy resin	0.03	kg	0%	2%	3.08	1%	1.64	0%	0.82	1%	1.03	1%	2.88
Packaging	Corrugated cardboard	1.40	kg	21%	3%	0.15	4%	0.18	2%	0.09	0%	0.01	1%	0.04
	Packaging tape	0.03	kg	0%	1%	1.81	0%	0.45	0%	0.45	3%	6.10	1%	2.71

* Values are % of total product impacts and will not add to 100% due to the impacts of other inputs throughout the lifecycle, including transportation, energy use and waste.

** Impact factor is defined as the % of the impact divided by the % of weight of the material in the product. An impact factor greater than 1 indicates that more weight of an environmental release occurs from the material than the weight of material that is used in the product.

From the trends analysis in Table 17, the manufacturing phase of the artificial Christmas tree is significant. The manufacturing phase includes the sourcing of raw materials. As such, it is valuable to understand which raw materials are significant contributors.

From Table 18, polyvinylchloride (PVC) used for the branches, tree stand and tree top insert has the highest impacts when compared to the other raw materials in the artificial Christmas tree. Going further into each impact indicator, the raw material that contributes the most to greenhouse gas (GHG) emissions is PVC followed by the streel sheets used for the tree pole, metal hinge and metal fastener. Impact factor for GHG represents how GHG intensive the raw material is; i.e. percentage of total GHG emissions to the percentage weight of that raw material in the overall product. For example, epoxy resin has a GHG impact factor of 3.08 which means that it produces a lot of GHG emissions relative to the amount of epoxy resin used in the overall product.

Similarly, for acidification potential (AP), PVC causes highest acidification followed by steel used in the branches. Polypropylene used for yarn on the branches causes the largest eutrophication impact. Again, PVC has the highest smog potential and primary energy demand among all the raw materials used, followed by steel used in branches.

Table 19 Percentage impact of raw materials and transportation of artificial trees

GHG		AP		EP		Smog		ADP	
64%	Raw Materials	38%	Raw Materials	62%	Raw Materials	35%	Raw Materials	82%	Raw Materials
13%	Transportation	44%	Transportation	27%	Transportation	51%	Transportation	12%	Transportation
22%	Other	18%	Other	12%	Other	14%	Other	6%	Other

Among the various life cycle phases, raw materials (within manufacturing) and transportation are major contributors to environmental impacts. Raw materials are primarily responsible for greenhouse gas emissions, eutrophication of water sources and use of non-renewable energy. Transportation mainly causes acidification of water, air and soil and smog in the atmosphere. Use phase and end-of-life are not the main causes of the above described impacts.

Impacts Associated with Transportation

Transportation impacts of the customer to the store to purchase an artificial or real Christmas tree can be understood by viewing the "Transport" life cycle phase in the results. In general, customer transportation can significantly impact the results. For instance, travel to the store to purchase an artificial Christmas tree is estimated to result in 2.41 kg CO_2e. Travel to purchase a real Christmas tree is estimated a 1.80 kg CO_2e. 8.04 km (round trip). Both of these values include the 8 km roundtrip of the customer to the retailer. The difference between these two numbers comes from the fact that the artificial Christmas tree includes transportation from port to storage and storage to retailer and the real Christmas tree includes transportation from farm to retailer. From a one year perspective, the transportation impacts of the real Christmas tree are less than then the impacts from the artificial Christmas tree. However, this is only for the one year scenario. When the multi-year scenarios are considered the real Christmas tree has a much larger impact because the transportation must happen annually for the real Christmas tree.

A major assumption when it comes the transportation impacts is that the customer travels to the retailer only to purchase a tree and that no other items are purchased.

Break-Even Analysis

Table 20 Break-even Analysis for artificial vs. Real Christmas Trees

Environmental Metric	Composting	Incineration	Landfill
Primary Energy Demand (PED) Non renwable	3	N/A	3
Acidification Potential (AP)	4	14	2
Eutrophication Potential (EP)	1	1	1
Global Warming Potential (GWP)	4	3	N/A
Smog Potential	5	16	4

Table 20 highlights the break-even years between the artificial Christmas and real Christmas trees. Some values are marked as "N/A" as they are negative number and cannot be compared. These values represent the number of years (Christmas seasons) that the artificial Christmas tree would have to be reused to be lower than the impacts of that many real Christmas trees (for a specific end-of-life scenario). For example, one would need to reuse the artificial Christmas tree for 4 seasons to have a lower impact than using a natural tree each year and then composting the tree.

Breakeven years can dramatically change based on environmental metrics and end-of-life scenarios. This makes it difficult to summarize the impacts of an artificial Christmas tree versus a real Christmas tree. However, impacts need to be summarized to make a complicated life cycle assessment study useful for the average, non-technical consumer and/or business leader.

From Table 20, we can calculate that the average breakeven point is 4.7 years. However, this calculation takes into account the outlier of the breakeven point for Smog Potential and acidification potential in the Incineration end-of-life scenario.

Energy Reduction in the Manufacturing of artificial Christmas trees

In providing primary data, the client made note that there has been a significant reduction in the manufacturing energy required to product an artificial tree. Overall, there has been a 43% reduction in the energy use in the manufacturing process of the artificial Christmas tree. However, the global warming potential has reduced by only 4% (Table 21). This can be attributed to the fact that the majority of the greenhouse gas emissions produced are due to raw materials and not energy used during manufacturing.

A further analysis was conducted to assure that modeling decisions in the first and second LCAs did not contribute to the disproportioned reduction between manufacturing energy and GHG emissions. This analysis evaluated the energy usage in manufacturing from the legacy LCA by running it through our current model. This analysis produced a result of 14.8 kg of CO_2 equivalent (greenhouse gas impact) for the legacy data in the current model, whereas the current data produces a result of 14.2 kg of CO_2 equivalent run through the same model. Thus, the greenhouse gas emissions produced due to manufacturing have been reduced although not as significantly as the relative reduction in manufacturing energy.

Table 21 Energy reduction impact for artificial Christmas tree

	Legacy LCA	Present LCA	Percent Reduction
GWP (kg of CO2 equiv.)	14.8	14.2	4%

This analysis indicates that environmentally preferable manufacturing decisions will be more effective by targeting life cycle phases other than the energy used in the manufacturing process. For instance, utilizing different raw materials (recycled PVC instead of virgin, for example), has the potential to significantly improve the environmental profile of artificial Christmas trees more than reducing manufacturing energy use.

Uncertainty Analysis

While this LCA study utilized best available data for each scenario studied, there is always uncertainty in life cycle assessment studies. In particular, uncertainty increases with the use of proxy datasets within the LCA model used as well as increases when secondary data is utilized.

For this study, the artificial Christmas tree results relied heavily on primary data while the natural tree results relied heavily on literature review. More specifically, manufacturing data was available from member manufactures of the American Christmas Tree Association. Thus 100% of manufacturing data of the artificial Christmas tree is considered primary data. On the other hand, we had to rely solely on a literature review for data for the real Christmas tree because there are no growers who are members of the American Christmas Tree Association. This difference may lead to greater uncertainly in the results than if primary data were available for both of the two tree types.

Additionally, the natural tree utilized specialty chemicals in the cultivation processes and LCI datasets were not readily available for these materials, so proxy datasets were utilized in the model. These two factors caused the natural tree results to have a higher level of uncertainty than the artificial Christmas tree results.

Similarly, end-of-life scenarios for the natural tree had varying levels of uncertainty in the results. Landfilling and incineration have well-documented LCI datasets available while composting did not. Therefore, a literature review was utilized for the composting scenario, causing a higher level of uncertainty.

Finally, while the LCI datasets within the GaBi software are well documented and have been updated within the past year to decrease the uncertainty levels as much as possible, there is some inherent uncertainty in the background modeling utilized by thinkstep. More information on this can be found at http://www.gabi-software.com/fileadmin/GaBi_Databases/GaBi_Modelling_Principles_2017.pdf.

Comparison with Previous LCA

LCA studies are snapshots in time. The information from an LCA can help establish a benchmark from which to identify areas of improvement – and in doing so, offer a way to reduce the environmental footprint for a particular product across the full life cycle. In 2010, an LCA was conducted to compare the impacts associated with a real Christmas and an artificial Christmas tree. Part of the client's desire in conducting a follow-up LCA was to evaluate how changes in the past 7 years may have impacted the overall results of the real Christmas and artificial Christmas trees and help identify areas to further reduce impacts to the environment of both types of trees across their life cycle.

In conducting this study, findings showed that while updated manufacturing data was available for the artificial Christmas tree, little updated information on the life cycle of real Christmas trees has become available.

In general, the results of this LCA vary from the previous LCA and the results of the two LCAs should not be directly compared. This incomparability stems from several key elements, mostly owing to differences in methodology, and include:

4) Different LCA practitioners from two different companies conducted the studies.
5) Availability and quality of background data (GaBi datasets) has changed in the past 7 years.
6) Possible differences in handling and modeling biogenic carbon sinks during cultivation and carbon releases during end-of-life.

Thus, the specific impact results in the two LCAs should not be directly compared. For instance, users of this document should not consider that the overall GWP footprint of the artificial Christmas tree has been reduced from 18.58 CO_2e (previous report) to 17.91 CO_2e (current report).

However, the results of the two studies do support some important generalizations as well as trend information. These are basic trends that can be understood by looking at both of the reports individually and include:

4) Both studies indicate that the impacts of sourcing of raw materials is the number one contributor to the environmental impacts across all categories for the artificial Christmas tree.
5) Both studies indicate that End-of-life treatment options for real Christmas trees significantly impacts the overall footprint of these trees.
6) Both studies indicate roughly a 5-year average payback period as an appropriate rule of thumb.

WORKS CITED

Baumgarten, A., Furst, A., Keller, G., Mutsch, F., Raith, F., & Schuster, K. (2000). *Empfehlungen für die sachgerechte Düngung von Christbaumkulturen (Recommendations for the proper fertilization of Christmas tree crops).* Vienna: ederal Research and Training Center for Forest, Snow and Landscape Research.

Boldrin, A., Andersen, J., Moller, J., Christensen, T., & Favoino, E. (2009). Composting and compost utilization: accounting of greenhouse gases and global warming contributions. *Waste Management & Research, 27*(8), 800-812.

Bureau of Transportation Statistics. (2008). *2007 Commodity Flow Survey United States Prelimnary. Table 5.* Bureau of Transportation Statistics.

Energy Research Center of the Netherlands (ECN). (n.d.). Phyllis: the composition of biomass and waste. *Phyllis, 4.13*.

Hinesley, L. E., & G. A. Chastagner. (2016). *Christmas tree keepability. p. 650-658. In: Gross, Kenneth C., Chien Yi Wang, and Mikal Saltveit (eds.). The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Crops. Agriculture Handbook 66, revised. USDA, Agricultural Research Service, Beltsville Area*. http//www.ba.ars.usda.gov/hb66/index.html

Hinesley, L., & Wright , R. (1989). Biomass and nutrient accumulation in Fraser fir Christmas Trees. *HortScience, 24*, 280-282.

Hundley, D., & Owen, J. (2005). C*hristmas Tree Production in North Carolina. Calibrating a Backpack Sprayer for Chemical Mowing.* NC State University.

Johnson, L., Lippke, B., Marshall, J., & Comnick, J. (2004). *Forest Resources Pacific Northwest and Southeast.* Consortium for Research on Renewable Industrial Materials.

Konsumo. (2008). *Weihnachtsbaum auch: Christbaum, Tannenbaum. (Christmas)*. Retrieved from http://www.konsumo.de/informieren/Weihnachtsbaum

Kuhns, L. (2004). *Crop Profile for Christmas Trees in Pennsylvania. General Production Information.* The Pennsylvania State University, Horticulture.

NCDA&CS Agricultural Statistics Division. (1996). *Agricultural Statistics - Christmas Trees.* NCDA&CS Agricultural Statistics Division.

Spectrum Analytic Inc. (2009). *A Guide to Fertilizing Christmas Trees.* Spectrum Analytic Inc.

U. S. Environmental Protection Agency. (2009). WAste Reduction Model.

US EPA. (2015). *Composting, WARM Version 13.* US EPA. US EPA.

Wahmhoff. (n.d.). *QUICK TREE FACTS from the National Christmas Tree Association*. Retrieved October 12, 2017, from Wahmhoff Farms Nursery: http://www.mitrees.com/

APPENDIX A – COMPLIANCE STATEMENT

Industrial Ecology Consultants
35 Bracebridge Road
Newton, Massachusetts 02459

Critical Review by Panel of External Experts
The Critical Review Panel was charged with reviewing and commenting on the life cycle assessment (LCA) study titled "Comparative LCA of the Environmental Impacts of Real Christmas and Artificial Christmas Trees". The study was conducted by WAP Sustainability Consulting by Mr. Brad McAllister. This LCA was conducted to compare the life cycle impacts of artificial Christmas trees and real Christmas trees. The results are to be used to make public statements about the environmental performance of the two products. The following is the final review statement by the external review panel based on the March 16th, 2018 report version.

Panel Members
Thomas Gloria, Ph.D. LCACP-03 (Panel Chair)
Industrial Ecology Consultants and
Program Director, Sustainability
Division of Continuing Education
Faculty of Arts and Sciences, Harvard University

L. Eric Hinesley, Ph.D.
Professor Emeritus, Horticultural Science
Department of Forestry and Environmental Resources
North Carolina State University

Mike Levy, BS, ME
Senior Director
Plastics Foodservice Packaging Group (PFPG)
Life Cycle Issues, Plastics Division, American Chemistry Council

Critical Review Tasks & Objectives
The critical review primarily involved the review and submission of comments on report drafts until such comments were adequately addressed by WAP Sustainability Consulting.

Per International Organization of Standardization (ISO) 14044:2006(E) *Environmental management – Life cycle assessment – Requirements and guidelines*, the primary objective of the critical review process included the following to ensure conformance with applicable standards:
- The methods used to carry out the LCA were consistent with the applicable international standards
- The methods used to carry out the LCA were scientifically and technically valid
- The data used were appropriate and reasonable in relation to the goal of the study
- The interpretations reflected the limitations identified and the goal of the study, and
- The study report was transparent and consistent.

Review Results
The overall review was conducted in an equitable and constructive manner. All comments were addressed and all open issues resolved. There were no dissenting opinions held by the reviewers or the commissioner upon finalization of the review. As such, after an exhaustive three rounds of review of comments and responses by the panel members and WAP Sustainability Consulting, based on the goals set forth to review this study, the review panel concludes that the study conforms to ISO 14044:2006 as a comprehensive study that may be disclosed to the public. In this case, ISO 14044, section 5.2 requires that a third-party report be made available to any third parties to whom the communication is made. The third-party report as well as the detailed review comments and the responses of the practitioner

will be made available from WAP Sustainability Consulting. Confidential contents may be removed from the report before sharing it with third parties.

Please note that this review statement by the panel members does not imply endorsement of the study results by the affiliated organizations.

Respectfully,

Thomas P. Gloria, Critical Review Panel Chair

21 March 2018
Newton, Massachusetts

APPENDIX B – VERIFICATION DOCUMENTS

Review of LCA study to ISO 14040/44 Standards
Reviewers: Thomas Gloria (Chair), Mike Levy, and Eric Hinesley

Date: 3/16/18	Document: **Comparative LCA of the Environmental Impacts of Natural Grown and Artificial Christmas Trees. January 2018**

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				Are the methods used to carry out the study consistent with the ISO 14040/14044 standards?			
1			TE	**ISO Requirement:** *General Aspects - LCA studies shall include the goal and scope definition, inventory analysis, impact assessment and interpretation of results.*	Requirement met		Closed
2			TE	**ISO Requirement:** *General Aspects - The requirements and recommendations of this International Standard, with the exception of those provisions regarding impact assessment, also apply to life cycle inventory studies.*	Requirement met		Closed
3			TE	**ISO Requirement:** *General Aspects - An LCI study alone shall not be used for comparisons intended to be used in comparative assertions intended to be disclosed to the public.*	Requirement met		Closed
4			TE	**ISO Reporting Requirement:** *General Aspects - LCA Commissioner, practitioner of LCA (internal or external)*	Requirement met		Closed
5			TE	**ISO Reporting Requirement:** *General Aspects - date of the report*	Requirement met		Closed
6			TE	**ISO Reporting Requirement:** *General Aspects - statement that the report has been conducted according to the requirements of ISO applicable standards (14040/14044)*	Requirement met		Closed
7			TE	**ISO Reporting Requirement:** *Goal of the study – reasons for carrying out the study.*	Requirement met		Closed
8			TE	**ISO Reporting Requirement:** *Goal of the study – its intended applications*	Requirement met		Closed
9			TE	**ISO Reporting Requirement:** *Goal of the study – its target audience*	Requirement met		Closed
10			TE	**ISO Reporting Requirement:** *Goal of the study – statement of intent to support comparative assertion to be disclosed to the public*	Requirement met		Closed
11			TE	**ISO Reporting Requirement:** *Scope of the study – function, including performance*	Requirement met Requirement met		Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				characteristics and any omission of additional functions in comparisons.			
12			TE	**ISO Requirement:** *Scope of the study – The product system to be studied.*	Requirement met		Closed
13			TE	**ISO Requirement:** *Scope of the study – The functions of the product systems, or in the case of comparative studies, the systems.*	Requirement met		Closed
14			TE	**ISO Reporting Requirement:** *Scope of the study* →The scope of an LCA shall clearly specify the functions (performance characteristics) of the system being studied. →The functional unit shall be clearly defined, measurable and consistent with the goal and scope of the study →The reference flow shall be defined. →Comparisons between systems shall be made on the basis of the same function(s), quantified by the same functional unit (s) in the form of their reference flows. →If additional functions of any of the systems are not taken into account in the comparison of functional units, then these omissions shall be explained and documented.	Requirement met		Closed
15			TE	**ISO Reporting Requirement:** *Scope of the study – functional unit, including consistency with goal and scope, definition, result of performance measurement*	Requirement met		Closed
16			TE	**ISO Requirement: Scope of the study – system boundary** *including omissions of life cycle stages, processes or data needs, quantification of energy and material inputs and outputs, assumptions about electricity production.* *→The selection of the system boundary shall be consistent with the goal of the study.* *→The criteria used in establishing the system boundary shall be identified and explained.*	Requirement met		Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				→Decisions shall be made regarding which unit processes to include in the study, and the level of detail to which these unit processes shall be studied. Reasons and implications of omitting life cycle stages, processes, inputs or outputs must be clearly stated and explained. *→The deletion of life cycle stages, processes, inputs, or outputs is permitted only if it does not significantly change the overall conclusions of the study* *→ Each of the unit processes **should** initially describe:* *(i) Where the unit process begins, in terms of the receipt of raw materials or intermediate products* *(ii) The nature of the transformations and operations that occur as part of the unit process* *(iii) Where the unit process ends, in terms of the destination of the intermediate or final products.* *→The cut-off criteria for initial inclusion of inputs and outputs, the assumptions on which the cut-off criteria are established and its effects on the outcome of the study **shall** be clearly described and assessed.*			
17			TE	**ISO Requirement: Scope of the study – LCIA** *→The selection of impact categories, category indicators, and characterization models used in the LCIA methodology shall be consistent with the goal and scope of the study and considered as described in 4.4.2.2. of ISO 14044.* *→An LCIA shall be performed using the same methodologies for studies intended to be used in comparative assertions intended to be disclosed to the public. Any differences between these systems regarding these parameters shall be identified and reported.*	Provide justification for not using all of the TRACI impact categories, including ecological toxicity and human health toxicity. Consider including the impact categories of land occupation and land transformation. Consider including the impact category of water consumption, particularly from irrigation if any. If not included, provide justification for its exclusion.	Discussed on page 21, last paragraph. Discussed on page 21, last paragraph. Water usage results included, page 33-34.	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				→*Interpretations to be used* →*Data requirements* →*Assumptions* →*Value choices and optional elements* →*Limitations*			
18			TE	**ISO Requirement: Scope of the study – DQ Requirements** Data quality requirements shall be specified to enable the goal and scope of the LCA to be met. It should address the following requirements: →Time-related coverage, geographical coverage, technology coverage, precision, completeness, representativeness, consistency, reproducibility, sources of data, uncertainty of information. →Comparative assertions intended to be disclosed to the public must address the above requirements. →Data quality should be characterized by both quantitative and qualitative aspects as well as by methods used to collect and integrate those data →Data from specific sites or representative averages should be used for those unit processes that contribute the majority of the mass and energy flows in the systems and are considered to have environmentally relevant inputs and outputs. →The treatment of missing data shall be documented for each unit process and missing location. (i) A "non-zero" data value that is explained (ii) A “zero" data value that is explained (iii) A calculated value based on the reported values from unit	Requirement met		Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				processes employing a similar technology			
19			TE	**ISO Requirement: Scope of the study – Critical Review** *Critical review considerations in the scope of the study:* *(i) Whether a critical review is necessary and how to conduct it.* *(ii) Type of critical review.* *(iii) Who would conduct the review and the level of their expertise. If the study is intended to be used for a comparative assertion intended to be disclosed to the public, interested parties shall conduct this evaluation as a critical review.*	Requirement met		Closed
20			TE	**ISO Requirement:** *Life Cycle Inventory Analysis – data collection procedures*	Requirement met		Closed
21			TE	**ISO Requirement:** *Life Cycle Inventory Analysis – qualitative and quantitative description of unit processes* *→The qualitative and quantitative data for inclusion in the inventory shall be collected for each unit process that is included in the system boundary.*	Requirement met.		Closed
22			TE	**ISO Requirement:** *Life Cycle Inventory Analysis – sources of published literature* *→When data have been collected from public sources, the source shall be referenced. For those data that may be significant for the conclusions of the study, details about the relevant data collection process, the time when data have been collected, and further information about data quality indicators shall be referenced.*	Requirement met		Closed
23			TE	**ISO Requirement:** *Life Cycle Inventory Analysis –* *→Measures should be taken to reach uniform and consistent understanding of the product systems to be modeled.*	Requirement met		Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1) Com-ment #	(2) Clause No./ Subclause No./Annex (e.g. 3.1)	(3) Paragraph/ Figure/Table/ Note (e.g. Table 1)	(4) Type of com-ment[2]	(5) Requirement	(6) Proposed change	(7) Decisions on each comment submitted	(8) Status Open/ Closed
				→Drawing unspecific process flow diagrams that outline all the unit processes to be modelled, including their interrelationships; *→Describing each unit process in detail with respect to factors influencing inputs and outputs;* *→Listing of flows and relevant data for operating conditions associated with each unit process;* *→Developing a list that specifies the units used;* *→Describing the data collection and calculation techniques needed for all* *→Providing instructions to document clearly any special cases, irregularities or other items associated with the data provided.*			
24	p. 20	Carbon uptake	TE	**ISO Requirement:** *Life Cycle Inventory Analysis –* *→All calculation procedures shall be explicitly documented and all assumptions made shall be clearly stated and explained.* *→The same calculation procedures should be consistently applied throughout the study.* *→When determining elementary flows associated with production, the actual production mix should be used whenever possible.* *→Inputs and outputs related to a combustible material (e.g. oil, gas, or coal) can be transformed into an energy input or output by multiplying them by the relevant heat of combustion.*	Provide additional details regarding the calculations of carbon uptake and the source of the 40% dry matter figure and the 49.7% carbon content.	Carbon uptake calculations added on Page 19.	Closed
25			TE	**ISO Requirement:** *Life Cycle Inventory Analysis – validation of the data* *A check on data validity shall be conducted during the process of data collection to confirm and provide evidence that the data quality*	Requirement met.		Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				requirements for the intended application have been fulfilled.			
26			TE	**ISO Requirement:** *Life Cycle Inventory Analysis – calculation procedures for relating data to unit process and functional unit* *→The quantitative input and output data of the unit process shall be calculated in relation to this flow.* *→The calculation should result in all system input and output data being referenced to the functional unit.* *→The level of aggregation [of inputs and outputs in the product system] shall be consistent with the goal of the study.* *→Data should only be aggregated if they are related to equivalent substances and to similar environmental impacts. If more detailed aggregation rules are required, they should be explained in the goal and scope definition phase of the study or should be left to a subsequent impact assessment phase.*	Requirement met.		Closed
27			TE	**ISO Requirement:** *Life Cycle Inventory Analysis – validation of data including data quality assessment and treatment of missing data.*	Requirement met.		Closed
28			TE	**ISO Requirement:** *Life Cycle Inventory Analysis – sensitivity analysis for refining the system boundary.* *→Reflecting the iterative nature of LCA, decisions regarding the data to be included shall be based on a sensitivity analysis to determine their significance.* *→The initial system boundary shall be revised, as appropriate, in accordance with the cut-off criteria established in the definition of the scope. The results of this refining process and the sensitivity analysis shall be documented.*	Requirement met.		Closed
29			TE	**ISO Requirement:** *Life Cycle Inventory Analysis – allocation principles and procedures,*	Requirement met.		Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				including documentation and justification of allocation procedures and uniform application of allocation procedures. *→The inputs and outputs shall be allocated to the different products according to clearly stated procedures that shall be documented and explained together with the allocation procedure.* *→The sum of the allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process before allocation.* *→Whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach.*			
30			TE	**ISO Requirement:** *Life Cycle Inventory Analysis – allocation procedures* *→ The study shall identify the processes shared with other product systems and deal with them according to the stepwise procedure presented below:* *Step 1: Wherever possible, allocation should be avoided by 1) dividing the unit process into two or more sub-processes and collecting the input and output data related to these sub-processes; 2) expanding the product system to include the additional functions related to the co-products [...]* *Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationship between them.*	Requirement met.		Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them (i.e. economic). *→ Some outputs may be partly co-products and partly waste. In such cases […] inputs and outputs shall be allocated to the co-products part only.* *→Allocation procedures shall be uniformly applied to similar inputs and outputs of the system under consideration.* *→The inventory is based on material balances between input and output. Allocation procedures should approximate as much as possible fundamental input/output relationships and characteristics.*			
31			TE	**ISO Requirement:** *Life Cycle Inventory Analysis – Allocation procedures for reuse and recycling* *→ Changes in the inherent properties of materials shall be taken into account. For the recovery processes between the original and subsequent product system, the system boundary shall be identified and explained, ensuring that the allocation principles are observed.*	Requirement met.		Closed
32			TE	**ISO Requirement:** *Life Cycle Impact Assessment - the LCIA procedures, calculations and results of the study* *The LCIA phase shall be coordinated with other phases* *of the LCA to take into account the following omissions and sources of uncertainty:* *→Whether the data quality of the LCI data and results is sufficient to conduct the LCIA in*	Requirement met.		Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				accordance with the study goal and scope definition. *→Whether the system boundary and data cut-off decisions have been sufficiently reviewed to ensure the availability of LCI results necessary to calculate indicator results for the LCIA.* *→Whether the environmental relevance of the LCIA results is decreased due to the LCI functional unit calculation, system wide averaging, aggregation and allocation.*			
33			TE	**ISO Requirement:** *Life Cycle Impact Assessment - impact categories and category indicators considered, including a rationale for their selection and a reference to their source.* ***4.4.2.2.1*** *The LCIA phase shall include the following* *mandatory elements:* *→Whenever impact categories, category indicators, and characterization models are selected in an LCA, the related information and sources shall be referenced.* *→Accurate and descriptive names shall be provided for the impact categories and category indicators.* *→The selection of impact categories, category indicators, and characterization models shall be both justified and consistent with the goal and scope of the LCA. It shall reflect a comprehensive set of environmental issues related to the product system being studied.* *→The environmental mechanism and characterization model that relate the LCI results to the category indicator and provide a basis for characterization factors shall be described.* *→The appropriateness of the characterization model used for deriving category indicator in the context of the goal and scope of the study shall be described.*	Requirement met.		Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				→LCI results other than mass and energy flow data included in the LCA (e.g. land use) shall be identified and their relationship to corresponding category indicators shall be determined.			
34			TE	**ISO Requirement:** *Life Cycle Impact Assessment - impact categories and category indicators considered,* *For each impact category, the necessary components of the LCIA include:* *→Identification of the category endpoint(s), characterization model, characterization factors and definition of the category indicator for given category endpoint.* *→Identification of the appropriate LCI results that can be assigned to the impact category, taking into account the chosen category indicator and identified category endpoint(s).*	Requirement met.		Closed
35			TE	**ISO Requirement:** *Life Cycle Impact Assessment - impact categories selection. In addition to the requirements in 4.4.2.2.1, the following recommendations apply to the selection of impact categories, category indicators, and characterization models:* *→The impact categories, category indicators, and characterization models should be internationally accepted.* *→The impact categories should represent the aggregated impacts of inputs and outputs of the product system on the category endpoint(s) through the category indicators;* *→Value-choices and assumptions made during the selection of impact categories, category indicators and characterization models should be minimized;* *→The impact categories, category indicators and characterization models should avoid double counting unless required by the goal and scope definition, for example when the study includes both human health and carcinogenicity;*	Requirement met.		Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				→The characterization model for each category indicator should be scientifically and technically valid, and based upon a distinct identifiable environmental mechanism and reproducible empirical observation; the extent to which the characterization model and the characterization factors are scientifically valid should be identified; *→Depending on the environmental mechanism and the goal and scope, spatial and temporal differentiation of the characterization model relating the LCI results to the category indicator should be considered.* *→The fate and transport of the substances should be part of the characterization model.*			
36	p. 12		TE	**ISO Requirement:** *Life Cycle Impact Assessment - impact categories selection. The environmental relevance of the category indicator or characterization model should be clearly stated in the following terms:* *(a)The ability of the category indicator to reflect the consequences of the LCI results on the category endpoint(s), at least qualitatively;* *(b) The addition of environmental data or information to the characterization model with respect to the category endpoint(s), including: the condition of the category endpoint(s); the relative magnitude of the assessed change in the category endpoint(s); the spatial aspects, such as area and scale; the temporal aspects; the reversibility of the environmental mechanism; and the uncertainty of the linkages between the category indicators and category endpoints.*	Due to inputs of herbicide for chemical mowing of real trees, a discussion regarding the exclusion of LCIA methods to assess toxicity results needs to be made.	A description was added to page 21 “ The TRACI impact categories of human health impacts and ecotoxicity…”	Closed
37			TE	**ISO Requirement:** *Life Cycle Impact Assessment -Assignment of LCI results to the selected impact categories (classification) should have:*	Requirement met.		Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				→Assignment of LCI results that are exclusive to one impact category; *→Identification of LCI results that relate to more than one impact category, including distinction between parallel mechanisms and assignment to serial mechanisms.*			
38			TE	**ISO Requirement:** *Life Cycle Impact Assessment - descriptions of or reference to all value-choices* *→The method of calculating indicator results shall be identified and documented, including the value choices and assumptions made.*	Requirement met.		Closed
39			TE	**ISO Requirement:** *Life Cycle Impact Assessment -Comparative Assertions.* *→The comparison shall be conducted category indicator by category indicator.* *→An LCIA shall not provide the sole basis of comparative assertions intended to be disclosed to the public of overall environmental superiority or equivalence, as additional information will be necessary to overcome the inherent limitations of LCIA.* *→Category indicators intended to be used in comparative assertions intended to be disclosed to the public should be internationally accepted.* *→Weighting shall not be used.* *→An analysis of results for sensitivity and uncertainty shall be conducted for studies intended to be used.* *→Category indicators intended to be used in comparative assertions intended to be disclosed to the public shall, as a minimum, be:* *(i) Scientifically and technically valid, i.e. using a distinct identifiable environmental mechanism and/or reproducible empirical observation.* *(ii) Environmentally relevant, i.e. have sufficiently clear links to the category endpoint(s) including, but not limited to, spatial and temporal characteristics.*	The requirement is met for the category indicators chosen. See comment #36.	A description was added to page 21. " The TRACI impact categories of human health impacts and ecotoxicity…"	Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
40			TE	**ISO Reporting Requirement:** *Life Cycle Impact Assessment – a statement that the LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.*	Requirement met.		Closed
41				**ISO Requirement:** *Life Cycle Interpretation – summary of the results* *→When the results from the LCI and LCIA phases have been found to meet the demands of the goal and scope of the study, the significance of these results shall then be determined.* *→All relevant results available at the time shall be gathered and consolidated for further analysis, including information on data quality.* *→The results of the evaluation should be presented in a manner that gives the commissioner or any other interested party a clear and understandable view of the outcome of the study.* *→The evaluation shall be undertaken in accordance with the goal and scope of the study.* *→During the evaluation, the use of the following three techniques shall be considered: completeness check, sensitivity check, consistency check.* *→The results of uncertainty analysis and data quality analysis should supplement these checks.*	Requirement met.		Closed
42				**ISO Requirement:** *Life Cycle Interpretation – Completeness check:* *→ If any relevant information is missing or incomplete, the necessity of such information for satisfying the goal and scope of the LCA shall be considered. This finding and its justification shall be recorded.* *→If any relevant information, considered necessary for determining the significant issues,*	Requirement met.		Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				is missing or incomplete, the preceding phases (LCI, LCIA) should be revisited or, alternatively, the goal and scope definition should be adjusted. If the missing information is considered unnecessary, the reason for this should be recorded			
43				**ISO Requirement:** *Life Cycle Interpretation – Sensitivity check:* *→ The sensitivity check shall include the results of the sensitivity analysis and uncertainty analysis, if performed in the preceding phases (LCI, LCIA).* *→When an LCA is intended to be used in a comparative assertion intended to be disclosed to the public, the evaluation element shall include interpretative statements based on detailed sensitivity analysis.* *→ In a sensitivity check, consideration shall be given to:* *(i) The issues predetermined by the goal and scope of the study* *(ii) The results from all other phases of the study* *(iii) Expert judgments and previous experiences.*	The three scenarios satisfy the requirement of conducting a sensitivity analysis. However, an uncertainty analysis has not been conducted.	The uncertainty analysis can be found in the conclusion section on page 37. "while this LCA study utilized….more information on this can be found at"	Closed
44				**ISO Requirement:** *Life Cycle Interpretation – Consistency check:* *If relevant to the LCA study the following questions shall be addressed:* *(a) Are differences in data quality along a product system life cycle and between different product systems consistent with the goal and scope of the study?* *(b) Have regional and/or temporal differences, if any, been consistently applied?* *(c)Have allocation rules and the system boundary been consistently applied to all product systems?*	Requirement met.		Closed

(1) Com-ment #	(2) Clause No./ Subclause No./Annex (e.g. 3.1)	(3) Paragraph/ Figure/Table/ Note (e.g. Table 1)	(4) Type of com-ment[2]	(5) **Requirement**	(6) **Proposed change**	(7) **Decisions** on each comment submitted	(8) Status Open/ Closed
				(d) Have the elements of the impact assessment been consistently applied?			
45				**ISO Requirement:** *Life Cycle Interpretation – Conclusions, limitations, and recommendations:* *→Conclusions shall be drawn from the study.* *→Recommendations shall be based on the final conclusions of the study, and shall reflect a logical and reasonable consequence of the conclusions.* *→Whenever appropriate to the goal and scope of the study, specific recommendations to decision-makers should be explained.* *→Recommendations should relate to the intended application.*	Requirement met.		Closed
46				**ISO Requirement:** *Life Cycle Interpretation – assumptions and limitations associated with the interpretations of results, both methodology and data related*	Requirement met.		Closed
47				**ISO Requirement:** *Life Cycle Interpretation – data quality assessment*	Requirement met.		Closed
48				**ISO Requirement:** *Life Cycle Interpretation – full transparency in terms of value-choices, rationales and expert judgments*	Requirement met.		Closed
49				**ISO Requirement:** *Critical Review – name and affiliation of reviewers*	Requirement met.		Closed
50				**ISO Requirement:** *Reporting* *→The type and format of the report shall be defined in the scope phase of the study.* *→The results and conclusions of the LCA shall be completely and accurately reported without bias to the intended audience.* *→The results, data, methods, assumptions and limitations shall be transparent and presented in sufficient detail to allow the reader to comprehend the complexities and trade-offs inherent in the LCA.* *→If results of the LCA are communicated to any third party, regardless of the form of*	Requirement met.		Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				communication, then a third-party report shall be prepared and made available (as a reference document) to any third party to whom the communication is made. The following aspects should be considered: *(i) LCA Commissioner and practitioner of LCA (internal* *or external)* *(ii) Date of report requirements of this International* *Standard* *(iii) Scope of the study (see 5.2c)* *(iv) Life cycle inventory analysis (see 5.2d)* *(v) Life cycle impact assessment (see 5.2e)* *(vi) Life cycle interpretation (see 5.2f)* *(vii) Critical review (see 5.2g)*			
				Additional Reporting elements for comparative assertions intended to be disclosed to the public			
51				ISO Requirement: analysis of material and energy flows to justify their inclusion or exclusion	Requirement met.		Closed
52				ISO Requirement: assessment of the precision, completeness and representativeness of data used;	Requirement met.		Closed
53				ISO Requirement: description of the equivalence of the systems being compared;	Requirement met.		Closed
54				ISO Requirement: description of the critical review process;	Requirement met.		Closed
55				ISO Requirement: an evaluation of the completeness of the LCIA;	Provide an analysis of the completeness of the category indicators chosen for the study.	See comment for #36 above	Closed
56	p. 12			ISO Requirement: a statement as to whether or not international acceptance exists for the selected category indicators and a justification for their use	State whether or not there is international acceptance of the category indicators selected.	Additional details provided on top of page 22.	Closed
57				ISO Requirement: an explanation for the scientific and technical validity and	Provide explanation.	Additional details provided on page 22.	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				environmental relevance of the category indicators used in the study;			
58				ISO Requirement: the results of the uncertainty and sensitivity analyses;	The three scenarios satisfy the requirement of conducting a sensitivity analysis. However, an uncertainty analysis has not been conducted.	This was added to the conclusion at the end of the study. Page 37. "While this study…More information on this can be found at"	Closed
59				ISO Requirement: evaluation of the significance of the differences found.	Requirement met.		Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				Are the methods used to carry out the study scientifically and technically valid?			
60			GE	Generally yes, however, an uncertainty analysis and evaluation of selected category indicators needs to be done.		These comments are addressed earlier in this document. (see comments 55,56,57 and new section on uncertainty analysis)	Closed
				Are the data used appropriate and reasonable in relation to the goal of the study?			
61			GE	Yes, the data used are appropriate and reasonable in relation to the goal of the study.			Closed
				Do the interpretations reflect the limitations identified and the goal of the study			
62			GE	The interpretations reflect the limitations of the study with the exception of the category indicators chosen.		These comments are addressed earlier in this document. (see comments 55,56,57 and new section on uncertainty analysis	Closed
				Is the report transparent and consistent?			
63			GE	Additional details need to be provided for carbon sequestration calculations for silviculture of the real trees and editorial comments as listed below. There are additional editorial comments below pertaining to Version 2 of the report.		Carbon uptake calculations added on Page 17. “Carbon uptake by the tree…for the next cultivation phases”	Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				General / Editorial Comments Goal and Scope			
64	Title Page		ED	"Artificial" is misspelled on front page.			Closed
65			GE	Be consistent for measures of mass and weight, including abbreviations. For example, on page 4 (Artificial Tree, paragraph 2, line 2), the abbreviation "ft." is used, but on page 5 (Functional Unit, line 2), the abbreviation "ft" is used. Just above that (page 5, Natural Tree, line 4), the word "foot" is used. Also, provide SI equivalents for all Imperial units.			Closed
66			GE	Although live trees sold with their own root systems represent a small fraction of Christmas trees sold, consider including this product system in the study, as they have been considered a more environmentally preferable alternative to cut natural trees, as well as artificial Christmas trees. If live trees are not included in the study, provide reasoning why they were not included,			Closed
67	Through-out		ED	Regarding terminology for real, natural, and live Christmas trees: Throughout this documents as well as subsequent reports, suggest using the term "real tree" or "live tree" for a cut Christmas tree. The term "naturally grown" is confusing. When we say "natural tree", it signifies a live tree that has not been sheared or shaped, e.g., a tree collected from the wild. Virtually all live Christmas trees are grown in plantations, and are sheared/shaped annually, e.g., Fraser firs.			Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				Owing to rapid growth, some species are shaped more than once annually, e.g., Virginia pine. These trees are not "naturally grown". The Christmas tree industry markets and advertises live trees as "real trees", a term that is absolutely clear in its meaning.			
68	Page 5 & 6		ED	This issue falls into the realm of grammar. In several places, a singular subject is used with a plural verb. For example, on page 5 (Natural Tree, last two lines), the wording says, ". . . the customer to enjoy the Christmas tree in their home." We see the same thing on page 6, Natural Tree, Use Phase. Most people, in ordinary conversation, use "their" to signify one person even though "their" is plural. One can use "his/her" to take care of the issue, but it's preferred to avoid.			Closed
69	Page 4 & 6		ED	This is another minor editorial issue, but we need to be consistent. When we say, "a tree 6.5 feet tall" (page 4, Artificial Tree, paragraph 2, line 2), there is no hyphen in "6.5 feet". If we say, a "6.5-foot tree" (page 6, Natural Tree, line 4), a hyphen is included because the word "6.5-foot" is an adjective. Revise throughout the text.			Closed
70	Page 7		ED	The functional unit is defined at the bottom of page 7. There is a mistake in line 2 for the "5-Year". It should be "1/2" rather than "1/5".			Closed
71	Page 6		GE	On page 6 (Use Phase, Natural Tree), what constitutes "packaging"? In most cases, the only packaging would be twine used to bale the tree. However, a small percentage of real trees are shipped mail-order, so that would involve cardboard boxes, similar to artificial trees.			Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				Please describe the packing options under consideration in the study.			
72	Page 4 & 5		ED	On page 4 (Reasons for Carrying . . ., lines 2-3), the wording is "the two product's environmental footprint". I think it reads better to reword as, "the environmental footprint of the two products". Another similar instance occurs on page 5 (line 5) where it says, "the retailer's facility". I suggest, "the retail facility".			Closed
73	Page 7		GE	On page 7 (End of Life, natural tree), one end-of-life option is incineration. What percentage of live trees actually take this path? In the area of North Caroline (more than 1 million people in this county), trees are either landfilled or composted. Quite a few trees are used to improve wildlife habitat, as for fish, but most are composted. To our knowledge, trees are not burned within municipalities. Provide references regarding the typical EoL of live or real trees.			Closed
74			GE	Provide explicit indication of the exclusion or inclusion of lights, ornaments and stands. Some artificial trees are sold with lights, particularly – higher quality, more expensive options. Lights on real trees are put on and taken off each year. High quality Christmas tree stands will last many years.			Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				Stands that come with artificial trees are less durable, so they might better fit the stated assumptions.			
75			ED	The document is typed in Times New Roman font. A font such as, Arial might be easier on the eyes to read.			Closed
				General / Editorial Comments Draft Report			
76	p. 3		ED	change Mike Levy's title to, "Senior Director, American Chemistry Council, Life Cycle Issues and Plastics Foodservice Packaging Group		Edit made	Closed
77	p. 4		ED	It's not appropriate to target the critical review team as a "target group/audience". The role is defined under ISO for comparative assessments as a requirement to have critical review. The target audience for this will be to general public as well as ACTA members.		Edit made, Reference to critical reviewers was removed.	Closed
78	p. 5		ED	"Real Tree', lines 1, 3, and 5; also, remainder of the report. It is 'Fraser fir', not 'Fraser Fir'.		Edits made.	Closed
79	p. 5		GE	'Functional Unit', par. 2, line 5. "tree stand for the Real Christmas Tree" ? Line 1 of p. 5 has Artificial Christmas Tree (first letter capitalized in each word). Be consistent throughout report.		Edit made, Top of page 6 and others area. We elected to only capitalize Christmas, not tree or real/artificial.	Closed
80	p. 4		ED	'Artificial tree', line 1. It is best to keep verb tense the same within a sentence. Suggest: "The artificial tree that was modeled in this study represented"		Edit made, page 4.	Closed
81	p. 6		ED	For the 5-year scenario, how do you explain 1 artificial Christmas tree is equal		For all three scenarios, the tree stand for the natural tree will last 10 years. Based on this fact, a 1 year study will have 1/10	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				to 5 real Christmas trees and ½ of the real Christmas tree's stand? One would think you would have to have a full stand – no such thing as a life cycle for ½ of a stand.		of the impact of the tree stand, a 5 year study will have 5/10 (1/2) of the impact of the tree stand, and a 10 year study will have 10/10 (1) of the impact of the tree stand.	
82	p. 7		ED	top of page, Table 'End of Life', column 3, line 1. "Handling of a real Christmas tree can vary"		Edit made	Closed
83	p. 8		ED	Change title to, "… Representativeness of data quality is shown below …." The term "Data Quality Scores" is misleading – we're not scoring any data quality		Edit made	Closed
84	p. 15		ED	"USE'. Punctuation: "is considered unlit and undecorated; hence, these impacts"		Edit made	Closed
85	p. 15		ED	Table 4, last column. Center the text.		Edit made	Closed
86	p. 18		ED	Life Cycle Inventory. For the first stage (1) Manufacturing/ cultivation should be clarified, and perhaps changed to read …."(1) Manufacturing (artificial tree)/Cultivation (real tree) …."		I believe that this change is needed on page 13, not page 18 of the original. If that is the case, the change has been made to further clarify the first stage. This change has been made on page 12 of the new document.	Closed
87	p. 22		TE	"REAL TREE METHODOLOGY' Line 1. A real tree is used in the last year of its life, so there is no additional year beyond that. Lines 4 &5. Fraser fir (Ff) normally is grown at a 5 ft x 5 ft spacing in the field = 1742 trees/acre = 4302 trees/ha. This equals an area of 2.31 m^2 per tree.		Clarified language to show that the final year of it's life is the year in which it is used. We have assumed tree density to be 4000 trees per hectare, which gives the area occupied by one tree as 2.5 m^2. This number is comparable to the number	Closed

(1) Com-ment #	(2) Clause No./ Subclause No./Annex (e.g. 3.1)	(3) Paragraph/ Figure/Table/ Note (e.g. Table 1)	(4) Type of com-ment[2]	(5) Requirement	(6) Proposed change	(7) Decisions on each comment submitted	(8) Status Open/ Closed
						suggested (2.31 m^2 per tree). This description has been added on page 14. “The tree density when planted…per hectare”	
88	pp. 22-23		TE	‘Cultivation’. The usual production cycle for a 6.5-ft Fraser fir is as follows: 3 years in a seedbed outdoors – target density about 20 to 30 seedlings per square foot. Move seedlings to a transplant bed for an additional 2 years – density about 6 transplants per square foot. Move transplants to the field for an additional 6 to 8 years in the field – density of 1742 trees per acre = 4032 trees/ha. I think 11 years to produce a 6.5-foot tree is somewhat excessive. A more typical range life span is 6 to 8 years. Alternatively, seedlings can be grown in containers in a greenhouse under special conditions for one year, and then another 2 years in transplant beds, and finally planted in the field. This cuts about 2 years off the production cycle, but has different energy requirements that are associated with greenhouses. ‘SEED TO YOUNG TREES’.		The lifecycle of the tree described in the report is as follows: Year 0 – year 2 – Seedbed Year 2 – year 4 – Transplant bed Year 5 – year 11 – growth in field followed by harvesting Packaging foil is assumed to be used to protect the seedlings when transplanting them from the seed bed to the transplant bed. Language for pruning has been changed on page 15.	Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				Line 1. Seeds are machine-planted to attain a density of about 30 seedlings per ft^2 = 320 plants/m^2. Line 5, packaging foil? Growers who produce their own seedlings and transplants normally dig the seedlings, pack them into boxes, and move directly to transplant beds where they are machine planted. Nurseries often must package and hold seedlings in cold storage 4 to 8 weeks before the plants are picked up by customers. Cold storage involves other energy expenditures and costs. Some plants are shipped to customers. Line 8. Change wording to "the tree is pruned annually with hand pruners"			
89	p. 24		ED/ TE	line 7. I would refer to it as a "chain saw" rather than a motor saw. 'Fertilization', line. Should this say, "summarized in Table 7"? Table 7. Origin of numbers (??) Consider nitrogen. The usual rate of N fertilization is about 100 lbs/acre (112 kg/ha) = 0.0023 lbs/ft^2 of nursery bed. Are these numbers for the weight of elemental N, or the weight of the fertilizer material? Same question applies to P and K. The amount of fertilizer depends on the specific fertilizer, e.g., ammonium nitrate is 33% N, so 300 lbs/acre (0.0069 lbs/ft^2) is needed to achieve a rate of 100 lbs/acre of elemental N. Di-ammonium phosphate is 18% N, so it would require 555 lbs/acre (0.0115 lbs/ft^2). Coated		Changed "motor saw" to "chain saw" on page 16. Changed table number to Table 7. Source of numbers in Table 7 has been mentioned in the preceding paragraph. In review, we found an error in our calculations based on misinterpretation of the background report in which the GaBi Dataset was built from. The table has been updated to reflect this. The new numbers are: N: 712.86 kg/ha over the 4 year period P: 128.9 kg/ha over the 4 year period K: 0, not applied onsite.	Closed

(1) Com-ment #	(2) Clause No./ Subclause No./Annex (e.g. 3.1)	(3) Paragraph/ Figure/Table/ Note (e.g. Table 1)	(4) Type of com-ment[2]	(5) Requirement	(6) Proposed change	(7) Decisions on each comment submitted	(8) Status Open/ Closed
				urea is about 38% N, so that material would require 263 lbs/acre = 0.0060 lbs/ft^2. Growers use quite a bit of di-ammonium phosphate because the analysis is fairly high, and it offers the advantage of providing N and P in the same material. The energy required to mine and manufacture these materials can vary significantly. p. 16, Table 7. As in the first review, reviewers are still having issues with the figures presented in Table 7. In the paragraph above the Table, the meaning of third sentence: “This represents the background data (ref) for the “reforestation” data set, and not the data directly incorporated into the model.” Based on the knowledge of the reviewers, growing Fraser fir, the numbers in Table 7 are not plausible. As discussed in the earlier review, Fraser fir is grown for 3 years in seedbeds at a target density of 30 seedlings per square foot (323 per m^2), and then moved into transplant beds for another 2 years at a density of 6 plants per square foot (64 per m^2). Historically, the general rate of fertilization is about 100 lbs/acre of N (113 kg/ha) annually. Lime and phosphorous are usually incorporated before seeding, and not added annually. Two of the more common N materials are ammonium nitrate (33% N) and coated urea (38% N). See reference: *Huxster, W.T. Jr. and J.S. Shelton. 1981. Management of small Fraser fir line-out or*		Are these numbers more plausiable? We will also note that when conducting our LCA study, our determination was that the dataset that uses this information (Reforestation, High intensity, US SE) was the best available approximation of the impacts of reforesting. This data is from USLCI, was peer reviewed and integrated into a GaBi dataset to be used in a model. While the dataset choice is not perfect, we have listed the use of the Reforestation dataset as a limitation and data quality gap, which is what ISO14044 would require.	

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				transplant beds. North Carolina Agric. Ext. Serv., Christmas Tree Notes CTN-002. Seedlings also are produced in containers in greenhouses. The reviewers do not know the proportions of Ff seedlings that are produced in soil nurseries outdoors as opposed to greenhouses. In a greenhouse, seedlings can be grown in one year to a size comparable to plants 3 years old outdoors. In greenhouses, fertilization is with controlled-release fertilizers (CRF), usually 15-9-12 or 18-6-12, incorporated into the growing medium at rates of 6 to 9 lbs per cubic yard. The typical volume of a container cell might be 10 to 16 cubic inches. Thus, one cubic yard of mix can do 3787 cells. Assuming 6 lbs per yard of CRF, this breaks down to 0 00158 lbs per cell for a cell volume of 16 cubic inches. The number of cells per square foot of bench space in the greenhouse averages about 30. Therefore, the fertilizer rate per square foot of bench space would be 30 x 0.00158 = 0.047 lbs/ft^2. It is simpler to deal with an outdoor nursery production system than a greenhouse system, so for purposes of this LCA, it is recommended that this approach be taken.			
90	p. 24/25		TE	Table 8. General observations: Are the units supposed to be kg/ha or kg/tree? I believe it should be kg/tree. Fertilizer materials: Ammonium sulfate is not used very often.		Changed to kg/ tree in Table 8. Fertilizers used were based on literature review. Sources are referenced in Table 8	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				Magnesium sulfate is used in only small amounts, typically as a foliar feed late in the production cycle. I have never heard of phosphoric acid fungicide (??) Calcium carbonate is one form of lime, which might be used to alter soil pH perhaps twice during the tree life cycle. The usual rate is 1000 to 2000 lbs/acre = 1120 to 2240 kg/ha. Glyphosate: How legitimate is it to use HCl as a proxy? Also, there is a number in each of the last 2 lines. It seems there should only be one number; either use the Kuhns estimate or the proxy, not both. Table 8, column 2. In regard to N (5 to 11 years in the field), the usual rate of fertilization in the field is 1 oz of elemental N per tree each year. The rate might increase to 1.5 oz/tree in the last 2 or 3 years when trees are larger. Let's say a tree is in the field 8 years. Using ammonium nitrate (33%N), this calculates to 8 oz of elemental N per tree = 1.5 lbs (0.68 kg/tree) of fertilizer material. Assuming 1742 trees/acre, this equals 2613 lbs/acre (2927 kg/ha) of fertilizer material. If a grower used ammonium sulphate (21% N) or di-ammonium phosphate(18% N), the weight of fertilizer material would be considerably greater than for ammonium nitrate. Conversely, if he used coated urea (38% N), which often occurs, the amount of fertilizer		Phosphoric acid is used as a proxy for fungicide. We reviewed the production process of typical fungicides and through the research it was determined that phosphoric acid is used as a major reagent in the product of fungicides. GaBi did not have an available dataset for a typical fungicide, so we felt it was appropriate to used phosphoric acid as a proxy. Glyphosate is being used as a chemical mower and as a herbicide. Similar rational to the phosphoric acid description about. HCl is a major reagents in the product of glyphosate and thus we felt it was an appropriate proxy. We also listed herbicide and chemical mower separately. Changes made to the units on Table 8.	

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				would be somewhat less compared to ammonium nitrate. The cost of various fertilizer materials varies a lot, and I assume the same generalization applies to the energy requirement to produce the materials. Table 8, last line – convert oz/acre to kg/ha.			
91	p. 26		TE	Finished tree to home -- "no additional packaging is done at the retailer". My experience is taking fresh cut Christmas trees home on my car is at a minimum twine is used to secure the tree on top of car roof and through doors/windows. While twine might not be a lot of packaging, it is usually used.		Added twine to model and updated results and report.	Closed
92	p. 26		TE	Consumption of 62 liters of water in 18 days is reasonable. If one assumes 4 qt/day, the figure calculates to 68 liters = 4 qt/day x 18 days x .945 liter/qt, but the difference does not influence the current assessment. The complete reference is needed in the LCA bibliography. That publication finally appeared in print last year. *Hinesley, L. E. and G. A. Chastagner. 2016. Christmas tree keepability. p. 650-658. In: Gross, Kenneth C., Chien Yi Wang, and Mikal Saltveit (eds.). The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Crops. Agriculture Handbook 66, revised. USDA, Agricultural Research Service, Beltsville Area.*		Consumption of water changed to 68 liters. Reference changed along with the citation.	Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				http//www.ba.ars.usda.gov/hb66/index.html			
93	p. 27		TE	Lines 1-2. There is tremendous variation in the weight and construction of stands. The best stands are all metal. 'End of Life', par. 4, 2nd sentence. I am skeptical about the 10% loss of its weight mass. Trees dry very fast after they are removed from water. More than half the tree weight is water. Where this could be important is calculating how much dry mass goes into various EOL scenarios. A lot is riding on this number. In my opinion, the statement is not needed, and could be deleted. In calculations of dry matter going into EOL scenarios, use the 0.54 water fraction (based on initial fresh weight) to determine dry mass. I think the 0.54 water fraction in Table 9 is fairly accurate. Table 9, last 4 entries. These numbers add to 100%. If plant material is incinerated, there is a residue (ash) that contains minerals such as K, Ca, Mg, Na, Si, etc. that can represent 1 to 2% of the dry matter. The table does not account for that.		We have now changed it to no loss of water due to evaporation. The section has been updated with the same (page 18). These numbers are used for composting and not for incineration.	Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				Note: The scientific literature shows that about half the dry plant mass is carbon, or slightly less. I have also verified this with my own research with Fraser fir (unpublished). Table 10, col. 3. Center the text. Use metric numbers and units in Table 'Landfilling of Real Tree'. Change wording to, "The estimated distance . . ."		Have made the suggested changes in table 10. Changed wording.	
94	p. 22		ED	Different scenarios, lines 4-7. I don't think the wording says what is intended: Option 2 (5 years) = 1 artificial tree and 5 real trees in 5 years. Option 3 (10 years) = 1 artificial tree and 10 real trees in 10 years.		Edit made on page 21	Closed
95	p. 21		TE	'Composting of Real Tree', line 2. Text says, "Total carbon lost during composting is 57.2%. If we dispose of a tree that weighs 30 lbs fresh weight, about 55% of that weight is water, so the dry mass is 13.5 lbs. The carbon content of that dry mass is about 50%, so the tree contains about 6.8 lbs of carbon. Line 2 says that 57% of that carbon is lost during composting = 3.9 lbs of carbon. Most of that carbon goes off as CO^2, with a small amount as methane. If the carbon is completely oxidized, it will yield about 14.4 lbs of CO^2.		Calculations for composting has been added to the section.	Closed

Review of LCA study to ISO 14040/44 Standards
Reviewers: Thomas Gloria (Chair), Mike Levy, and Eric Hinesley

Date: 3/16/18	Document: **Comparative LCA of the Environmental Impacts of Natural Grown and Artificial Christmas Trees. January 2018**

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				For comparison, the combustion of 1 gallon of gasoline releases about 20 lbs of CO[2] compared to 22 lbs for diesel fuel.			
96	p. 22		TE	Tables 11 and Table 12. I suggest centering the text in all columns. Question: Does the GWP analysis account for CO2 fixation in the trees during their life cycle in the field? All the CO2 fixed by a tree during its life cycle represents a net reduction in GWP potential. When the trees are composted or incinerated, the amount of carbon released is less than the amount present in the tree, so neither process can directly produce a net gain in GWP for a real tree. As I recall from the 2010 LCA, the greatest expenditure of energy associated with Christmas trees is the fuel used by a consumer on the round-trip between the retail lot and his/her home. Consequently, I can see where the GWP of securing a real tree each year could add up quickly, particularly in the 5-yr and 10-yr scenarios where a live tree is purchased each year. The point I want to stress is that the positive contribution of a real tree to GWP at its disposal cannot exceed the GWP of that tree during its life unless, of course, the fuel needed for transportation and disposal creates enough GWP to swing the balance to the plus side.		The GWP analysis accounts for the CO2 sequestered in the tree and the release of some of this CO2 at the end of life. The reason why the cultivation life cycle stage isn't as negative as you would expect relative to the end of life scenarios is that there are other GWP emissions during that stage. For instance, the transportation of the seedlings to the field, the production of the fertilizers, and the electricity in the greenhouse. All of these start to offset the carbon sequestration in the cultivation stage.	Closed
97	p. 23		ED	Fig. 2 and other similar Figures.		See comment #96.	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1) Com-ment #	(2) Clause No./ Subclause No./Annex (e.g. 3.1)	(3) Paragraph/ Figure/Table/ Note (e.g. Table 1)	(4) Type of com-ment[2]	(5) Requirement	(6) Proposed change	(7) Decisions on each comment submitted	(8) Status Open/ Closed
				I think readability would be better if a larger point size were used in the labels, captions, title, scales, etc. I'm having some difficulty understanding Fig. 2 and others like it. As discussed earlier, I do not readily see how it is possible for EOL of a real tree to create positive GWP, aside from the influence of fuel and energy used to transport and/or incinerate the tree or compost, which might surpass in impact any direct loss of carbon from the trees when they incinerated or composted. Perhaps the explanatory text could address this question. The impact of fuel usage by consumers should be stressed in the conclusions.			
98	p. 24		ED	par. 3, line 2. This only occurred a few times, but I think it is important to maintain wording that is unbiased in its tone. Example ". . . so that it is equal to the real tree . . ." -- same issue on p. 26, last paragraph, line 2, and elsewhere.		Change made, p23	Closed
99	p. 24		ED	par. 2, line 4. Reword: "real trees seem to have a greater GWP than artificial trees, but . . ."		Edit made, page 23	Closed
100	p. 28		ED	last par. , line 2. "is less than the real tree"		Section modified. Edit no longer required.	Closed
101	p. 35		ED	next to last par., line 7. "produces a lot of GHG emissions"		Edit made	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
102	p. 37		ED	par. 1, line 7. "have been reduced although not as"		Edit made	Closed
103	p. 37		ED	"Comparison with previous LCA', par. 3, line 2. "this difference stems from"		Edit made	Closed
104	pp. 37-38		GE	If still applicable, I think it again should be pointed out that the fuel usage by consumers to and from the retail lot is a major source of environmental impact, regardless of tree type. This could cause significant differences in comparisons of real and artificial trees over a 5- or 10-yr period.		**Impacts Associated with Transportation** Section added. (page 39)	Closed
105	p. 38		ED	line 1. "9-year"		Edit made	Closed
106	p. 39		ED	Need full reference for Chastagner and Hinesley. *Hinesley, L. E. and G. A. Chastagner. 2016. Christmas tree keepability. p. 650-658. In: Gross, Kenneth C., Chien Yi Wang, and Mikal Saltveit (eds.). The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Crops. Agriculture Handbook 66, revised. USDA, Agricultural Research Service, Beltsville Area. http//www.ba.ars.usda.gov/hb66/index.html*		Changed reference.	Closed
107	p. 34			2nd paragraph. "However, these occupy space on landfills for several hundred years if they release any carbon dioxide". I think eliminating "several hundred years" makes sense here, since there is no real way to document that. Statement.		Edit made	Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
108	p.46			"… The model is sensitive to the following assumptions and data, **and are subject to limitations …** "		Edit made	Closed
109	p. 47			Data Quality Analysis. This section seems too subjective – could use some metrics on how much was primary data, vs. literature and published data. Perhaps a discussion of "meaningful differences" based on data quality might be included to put this in perspective.		We have added an uncertainly analysis section to the report per other comments. This section also addresses, this comment around primary data vs. literature review.	Closed
110	p. 52			Comparison with Previous LCA. Typo – 3rd paragraph, 2nd line – change "steams" to "stems: This whole section is contradictory. ON the one hand it says in general the two LCA studies (this one and previous one) should not be directly compared – for 3 reasons. This seems to be a "disclaimer". But then it lists 3 generalizations they do draw from the two studies. It is recommended to the circumstances be explained or put in better context.		Edit for "stream" What we are trying to portray in this section is that the direct impact results should not be compared because of the 3 reasons listed in this section. This is a practical statement that is informed by ISO14040/44 regarding the non-comparability of results conducted by different practitioners in different settings. Again, this is related to comparing specific results values between the two reports. The 3 generalizations on the other hand, are related to similar trends of the two reports and not direct comparison of the results. Language added to this section "Thus the specific impact results in the two LCAs should not be directly compared. For instance, users of this document should not consider that the overall GWP footprint of the artificial tree has been reduced from 18.58 CO_2e (previous report) to 17.91 CO_2e (current report).	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
						However, the results of the two studies do support some important generalizations. These are basic trends that can be understood by looking at both of the reports individually and include:"	
DRAFT 2 COMMENTS							
111	General		ED	- This report seems disjointed and doesn't flow. I think it could be vastly improved and "screams for" a very short executive summary that can also be pulled out and perhaps used as a standalone making sure it specifically ties into the exact results. This executive summary should be inserted up front in the full study, incorporating elements from these various sections of the full study. A standalone executive summary of less than 10 pages can maybe help with the flow of the more detailed sections/tables/charts in the report. We all know many people want a short executive summary (but something relatable to actual findings) that they can use. - Here's what I would include in the Exec Summary: ○ Page 3 and 4 information – Goal and Scope, practitioners, peer review team ○ Page 4,5 and 6 – excerpts of the two product systems studied (not all the detail though) ○ Page 53 – Conclusions ○ Page 58 – Comparison with previous LCA		Added Executive Summary	Closed
112	p. 3	3rd Para, Line1	ED	Page 3 … May want to add the 4 sentences under page 4, "reasons for carrying out the		Have added the suggested description about ACTA.	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**2	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				study and intended appa9icton" right after the first paragraph on Page. 3. The American Christmas Tree Association (ACTA) commissioned this comparative LCA study. According to their website, "The American Christmas Tree Association is a non-profit organization whose mission is to educate the public with factual data to help consumers make intelligent decisions about Christmas trees and the Christmas tree industry." **Insert here:** This LCA was conducted in order to compare the life cycle impacts of artificial Christmas trees and real Christmas trees. The results will be used to make public statements about the environmental footprint of the two products. It is expected that the statements will be made online, in print in various publications and media and potentially on radio and television outlets.			
113	p. 5	3rd Para, Line1	ED	"Christmas tree", t is not capitalized.		"T" in Tree has been capitalized.	Closed
114	p. 8-9	Table 2	ED	The convention used in the report is to put a Table title at the bottom of the Table. However, this Table is several pages in length, so it might be helpful to readers in this instance to put the title at the top of the Table so that readers will immediately know the nature of the Table contents without having to drop down 2 pages to read the title.		Table title positions have been changed to appear before the table.	Closed
115	Throughout		ED	<u>Figures and Tables throughout LCA</u>. Readability and clarity would be better if a larger text size were used in the labels, captions, title, scales, etc. The text size for interior bars should be about 2X bigger. Using Fig. 2 as an example, the interior labels could be put above		The figures are created as per our internal template, which has been used and approved in previous studies. We would prefer not to change this since it is an editorial comment.	Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment2**	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				the bars where there is more space. Text of axis labels and legend labels should be larger. Text in the titles could be 2X to 3X larger. The title should grab the attention of the reader.			
116	Throughout		ED	Headings throughout LCA. One example is at the bottom of page 7; another is at the bottom of page 9. Don't put a heading on one page and the Fig., Table or text on the next page; they should begin on the same page. Use a "hard return" to skip to the top of the next page.		Headings have been changed throughout the report.	Closed
117	p. 15	Table 5	ED	Provide figures to 3 significant digits, or at least present only whole numbers.		Table 5 figures changed to whole numbers.	Closed
118	p. 16 & 17		ED	Bottom of p. 15. Seedbeds usually go for 3 years, not 2 years, although there are exceptions. p. 15, last item listed. Seedlings are not taken from the nursery bed to a greenhouse. Instead, they are taken from the nursery bed to a transplant bed. p. 15, last par., line 1. Line 1. Seeds are machine-planted initially to attain a density of about 30 seedlings per ft^2 = 320 plants/m^2. Seeding is not done by hand, at least not by big producers. p. 16, line 1. Change wording to "cultivation of transplants (years 2-4)". Usually the transplant period is years 4-5. p. 16, bullet #3. Change wording to "planting the transplants in the field" p. 16, bullet #4. Change wording to "Cultivation of tree in the field (years 5-11)"		Initial growth phase of 0-2 years is based off assumptions used in the previous study. A note was included in the report to state that 0-2 was an assumption that we selected and that in many cases seedbeds go for 3 years. Change made Density suggested by the reviewers and density assumed in our study are close. This was previously addressed in the previous round of this review. See comment 87 above, which was closed by the reviewers. Regarding the comments about hand planting. This is a assumption that was made base off of the GaBi dataset that was chosen for reforestation. The background report states hand planting. However, we have made an additional comment in the report to state:	Closed

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				p. 16, line 9. I suggest putting a blank line between this line and the last bulleted item.		"This assumption was made based off of background documentation (Johnson, Lippke, Marshall, & Comnick, 2004). In reality, bigger producers may plant mechanically." Change made. Change made. Change made. Change made.	
113	p. 17	Table 8	ED	Provide figures to 3 significant digits,		Change made.	Closed
113	p. 18		ED	Post-harvest Treatment at Farm. Fraser fir is not pruned at the time of harvest. Fraser fir, as well as other species that are graded in the field, are not required to have a pruned handle when harvested. *U. S. Dept. Agriculture. 1989. United States standards for grades of Christmas trees. USDA, Agric. Marketing Serv. 10 p.* There are three methods for pruning handles on Ff, and none occur during the harvest operation. First, branches are removed prior to harvest, and are subsequently used or sold by the grower to manufacture wreaths and greenery. Second, the handles are cleaned on retail lots		Statement on pruning changed.	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				when customers buy the trees. Third, the handles are trimmed by the customer before the tree is set up in the home. Line 2 of paragraph. Perhaps consider changing wording to "left undisturbed in the soil"		Second change made.	
119	p. 21	Table 10	ED	Round figures to 3 significant digits.		Change made.	Closed
120	pp. 24-34		ED	Layout of Figures. These comments apply to Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6 and Fig. 7. There is a heading at the top of each Figure, inside the box that outlines the Figure. At the bottom of each Figure, outside the box, is the caption or title for the Figure. I suggest omitting the heading at the top, and include the caption/title inside the box at the bottom. As mentioned in another comment, the text size should be larger for the Fig. title/caption than any of the text in the Figure. The headings in these Figures have more information than the current titles, so I think they should be substituted.		The figures are created as per our internal template, which has been used and approved in previous studies. We would prefer not to change this since it is an editorial comment.	Closed
121	p. 25	Para. 4, Line6	ED	Reword as, "Christmas seasons before it is equal to a real tree"" p. 24, par. 4, last line. Reword as, "must be used at least 3 years before its GWP is less than the real tree"		Edits made.	Closed
122	p. 28	Caption for Fig. 4	ED	Add a space -- "Fig. 4. Acidification potential . . ."		Space added.	Closed
123	p. 29	Para 4, Line 1	ED	This sentence has a comma splice. Change to "real tree scenario is 4, meaning that", or "real tree scenario is 4. This means that"		Change made.	Closed
124	p. 37	Conclusio ns		Suggest inserting a subtitle for the first paragraph (see bold italic below): Conclusions		Change made.	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				Summary: Main Contributors to Impacts – Artificial Tree and Real Tree Overall for the artificial tree, manufacturing seems to be the main contributor to majority of the impact indictors. From the global warming standpoint, manufacturing is the largest contributor for the artificial tree and end-of-life methods is the largest contributor for the real tree. For all the other indicators, cultivation is the largest contributor for the real tree.			
125	p. 39	Para 1 Line 1	ED	Omit “we can see that”		Change made.	Closed
126	p. 39	Para 2 Line 1	ED	Omit “we understand that”		Change made.	Closed
127	p. 39	Last Para Line 1	ED	Omit “we can see that”		Change made.	Closed
128	p. 40	Para 1 Line 5	ED	“8-km round-trip” or “8-km roundtrip”		Change made.	Closed
129	p. 40	Para 2 Line 1	ED	Omit “It should be noted that”		Change made.	Closed
130	p. 40	Para 2 Line 2	ED	Omit “purchase”		Change made.	Closed
131	p. 40	Table 20	ED	Table needs a better title, perhaps “Break-even analysis for artificial vs. real Christmas trees”. Near the bottom of Table 20, I suggest rounding 4.69 to 4.7 years.		Change made.	Closed
132	p. 40	Line 9	ED	Impacts wording is confusing -- “the transportation impacts of the real tree are less than the impacts for the real tree” (??)		Sentence corrected.	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment[2]**	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
133	p. 42	Para 1 Line 3	ED	"Therefore"		We are unclear of what you are requesting.	Closed
134	p. 43		ED	WORKS CITED. Hinesley and Chastagner reference is incomplete. Use the following: *Hinesley, L. E. and G. A. Chastagner. 2016. Christmas tree keepability. p. 650-658. In: Gross, Kenneth C., Chien Yi Wang, and Mikal Saltveit (eds.). The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Crops. Agriculture Handbook 66, revised. USDA, Agricultural Research Service, Beltsville Area.* *http//www.ba.ars.usda.gov/hb66/index.html*		Change made.	Closed
135	p. 42	Para 3, Line 2		Comparison with Previous LCA, suggest "mostly owing to differences in methodology, including"		Change made.	Closed
136	p. 42			Comparison with Previous LCA (page 58) – see some suggested edits (highlighted) **Comparison with Previous LCA** LCA studies are snapshots in time. The information from an LCA can help establish a benchmark from which to identify areas of improvement – and in doing so, offer a way to reduce the environmental footprint for a particular product across the full life cycle. In 2010, an LCA was conducted to compare the impacts associated with a real and an artificial Christmas tree. Part of the client's desire in conducting a follow-up LCA was to evaluate how changes in the past 7 years may have impacted the overall results of the real and artificial Christmas trees and help identify areas to further reduce impacts to the environment of both types of trees across their life cycle. In conducting this study, findings showed ~~we found~~ that while updated manufacturing data		Change made.	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				was available for the artificial tree, little updated information on the life cycle of real Christmas trees has become available. In general, the results of this LCA vary from the previous 2010 LCA. ~~and the~~ The results of the two LCAs should not be directly compared. This incomparability stems from several key elements, mostly methodical in nature, and include: 1) Different LCA practitioners from two different companies conducted the studies. 2) Availability and quality of background data (GaBi datasets) has changed in the past 7 years. 3) Possible differences in handling and modeling biogenic carbon sinks during cultivation and carbon releases during end-of-life. Thus, the specific impact results in the two LCAs should not be directly compared. For instance, users of this document should not consider that the overall GWP footprint of the artificial tree has been reduced from 18.58 CO_2e (previous report) to 17.91 CO_2e (current report). However, the results of the two studies do support some important generalizations as well as trend information. These are basic trends that can be understood by looking at both of the reports individually and include: 1) Both studies indicate that the impacts of sourcing of raw materials is the number one contributor to the environmental impacts across all categories for the artificial tree. 2) Both studies indicate that End-of-life treatment options for Real Christmas trees significantly impacts the overall footprint of these trees.			

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
				3) Both studies indicate roughly a 5-year average payback period as an appropriate rule of thumb.			
137	p. 1-2	Table of Contents	ED	There are two sizes of text.	I suggest using the same text size throughout Table.	Change made.	Closed
138	p. 3,	Par 3, Line 1	ED	Omit “Douglas”.	It should read as “Fraser fir”. The correct name is "Fraser fir", and “fir” is not capitalized.	Change made.	Closed
139	p. 4, p. 7 & Through-out		ED	There still is too much inconsistency in regard to protocol for tree names. For example, is it “Real Christmas Tree”, “real Christmas Tree”, or “real Christmas tree”? Same question applies to artificial trees. The convention probably does not matter much, but it should be consistent.	In any case, “Christmas” always is capitalized. Use the same convention throughout the document.	Change made.	Closed
140	p. 9 and other tables		ED	I think the text size in Table titles should be larger than the text in the Tables. Currently, it is much smaller. Normally, the title is bigger.		Change made.	Closed
141	p. 11	Back-ground Data	ED	Here, and in several other instances, I think this heading should go on p. 12 at the top of Table 2 to keep the heading and Table together on the same page. That will improve ease of reading.		Change made.	Closed
142	p. 18	par. 1 and 2	ED	Distance and weight should use metric units. Include English equivalents in parentheses, e.g., “8.0 km (5 miles)”, or “2.0 m (6.5 ft)”.		Change made.	Closed
143	p. 18		ED	Real Tree Methodology, line 2 – “11-year period”.		Change made.	Closed
144	p. 21		ED	Finished Tree to Home, line 1 – The word “a t” has an extra space.		Change made.	Closed
145	p. 22	Bottom of page	ED	Move “Landfilling of Real tree:” to the top of p. 23.		Change made.	Closed
146	p. 23		ED	Use metric, with English equivalents in parentheses, e.g., “32.2 km (20 miles)”.		Change made.	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com-ment #	**Clause No./ Subclause No./Annex** (e.g. 3.1)	**Paragraph/ Figure/Table/ Note** (e.g. Table 1)	**Type of com-ment**[2]	**Requirement**	**Proposed change**	**Decisions** on each comment submitted	**Status Open/ Closed**
147	p. 23	Last line	ED	Move to top of page 24 to keep the heading with its text.		Change made.	Closed
148	p. 25	Par 3 list	ED	There is no punctuation after (2) and (3). Is that correct? Same question also applies to the list on p. 22.		Change made.	Closed
149	p. 32	Par. 4 line 2	ED	Change "becomes better than" to "its AP potential is less than" the real tree.		Change made.	Closed
150	p. 38	Last line	ED	"2" = "two".		Change made.	Closed
151	p. 3	Par 1 lines 4, 5, & 6 Par 2, line 1	ED	To conform with the most recent convention, "tree" and "trees" should be lower case.		Change made.	Closed
152	p. 4	Results	ED	Par. 1, line 2 -- "Christmas trees" Par. 4, line 5 – "artificial tree"		Change made.	Closed
153	p. 7	Reasons	ED	line 4 –"Christmas trees" and "Christmas tree industry"		Change made.	Closed
154		Table Title through-out	ED	The new Table titles look good with the larger point size. I suggest doing the same enlargement with text in the titles for Figures 1-7 (pages 16, 28, 30, 32, 34, 36, and 38).		Change made.	Closed
155	p. 41	Conclu-sions	ED	"Christmas tree"		Change made.	Closed
156	p. 3	Par 3, line 5	ED	"Christmas tree industry", don't capitalize "tree".		Change made.	Closed

Type of comment: **GE** = general **TE** = technical **ED** = editorial