5-2018

# Sustainability Children's Book

Linden Cheek
*University of Arkansas, Fayetteville*

# SUSTAINABILITY CHILDREN'S BOOK

**Linden Cheek**

Biological Engineering Program

Biological and Agricultural Engineering Department

College of Engineering

University of Arkansas

Undergraduate Honors Thesis

## Table of Contents

**Table of Figures**

## Project Summary

As human driven climate change continues to alter our planet, persuading the general public to adopt sustainable living practices has become increasingly important. Storytelling has long been a part of human culture, and recent studies have emphasized the power of storytelling to influence the audience as a means of changing behavior. This project attempted to teach sustainable principles to primary school children through the creation of a scientific children's book. The book communicated the maxim of "reduce, reuse, recycle" by tracing a fictitious story of a town where children frequently buy new toys and throw the old toys away. The book explores the supply chain of toys and the market forces of supply and demand, focusing on the consumer's responsibility to not over-consume, i.e "reduce". It also presents the concept of "reusing" and "recycling" as alternatives to disposal of old toys. The book was evaluated for age appropriate language and concepts for K-5 students and adjusted to meet educational standards. It was then tested by reading it to a classroom of 2nd grade students. A discussion with the students following the reading showed that they understood the theme of the book and how they could apply it to their own lives. The project also included a life cycle analysis (LCA) of a stuffed animal, a representative toy from the story. The LCA showed that the largest contributors to the stuffed animal's impacts were the production of cotton used for its outer layer and the electricity used in its assembly. It also showed the impacts most damaging to human health were chiefly a result of the fossil fuels used to provide process energy.

## Introduction

As human driven climate change continues to alter our planet, persuading the general public to adopt sustainable living practices has become increasingly important. However, due to the complex nature of sustainability in combination with the often-conflicting information presented by the media, much of the general public has little understanding of sustainability, let alone how their own actions can either promote or diminish global ecosystem and human health.

In this project, I sought to address this problem through writing a children's story. Storytelling has long been a part of human culture, and recent studies have emphasized the power of storytelling to influence behavior. Character driven stories cause a release of oxytocin in the brain, a chemical known to promote empathy and cooperation with others. Well-written stories not only cause the audience to empathize with the main character, but motivate them to mimic the characters' behavior well after the story ends (Zak, 2014).

I sought to use the power of storytelling to promote sustainable behavior by writing a children's book. I selected young school children as my target demographic both because there is need for accurate non-fiction books for children and because instilling sustainability principles in people as children has potential to motivate sustainable behavior throughout their adult lives. This strategy can be compared to anti-smoking campaigns targeted at children to prevent lifelong addiction. These campaigns were found to be most effective when the advertisements featured material specifically targeted towards youths (Pechmann and Reibling, 2000).

To be considered successful, my book should meet two criteria. Firstly, it should successfully communicate its theme to the selected demographic; a child reading the book should be able to communicate the sustainable principles presented with more clarity than before reading. Secondly, the book should meet established educational standards of appropriate grade level language and themes so it could be easily incorporated into classroom curriculum. To test the first criteria, I read the book to a local 2nd grade class and obtained feedback. To test the second criteria, my educational advisor, Dr. Peggy Ward, and I compared my book to the Arkansas Science Standards for my target demographic to find the standards my story achieved (Arkansas Science Standards, 2016 & 2017).

It is also imperative to ensure that the information presented in my book is accurate. The story focuses on the supply chain of toys. While the story presents this supply chain in an overly simplified manner appropriate for children, it is still necessary to ensure none of the steps are misrepresented. To fact check my narrative I selected a stuffed animal as my representative toy and performed a Life Cycle Analysis (LCA) of the stuffed animal using SimaPro®. LCA is the current standard of sustainability analysis within the scientific community. Performing a LCA on the subject matter of my children's story allows me to tell the same story of sustainability in supply chain through parallel formats, developing both my skills as an educator and an engineer.

According to *Introduction to LCA with* SimaPro, "LCA is a tool for quantifying the environmental performance of products taking into account the complete life cycle, starting from the production of raw materials to the final disposal of the products" (Goedkoop et al., 2016). The LCA helped inform writing the book by identifying the component of a toy that had the largest impact on sustainability to represent the supply chain.

Since the Honor's Thesis exists as a method to expose undergraduate students to research and as a way to increase engineering skills, the LCA component of this project was also performed so I could learn how to use SimaPro software and create an LCA. I completed a basic analysis of the impacts of a model stuffed animal, both to compare the impacts of its individual components as well as to compare the impact of its assembly and disposal.

## Literature Review

Storytelling has long been part of human culture and recent scientific studies have shown how the chemicals released in human brains while listening to stories nurture feelings of empathy and encourage certain behaviors. In a Harvard Business Review article titled “Why Your Brain Loves Good Storytelling”, Paul J. Zak, the founding director of the Center for Neuroeconomics Studies and professor of Economics, Psychology, and Management at Claremont Graduate University, explains how these chemicals work. His lab discovered that oxytocin, a chemical released in the brain to signify trust, strengthen relationships and promote cooperation, is consistently released during character-driven stories. This release has been shown to motivate voluntary cooperation. However, Zak’s research has also shown that this motivation is only communicated if a story can hold the listener’s attention. If their attention is held for enough time, the listener will begin to share emotions with the characters and, more importantly, be motivated to mimic character behavior after the story ends (Zak, 2014). A separate Harvard Business Review article, “How to Tell a Great Story”, compiles the work of several storytelling experts into a list of the components of successful stories. The first step to writing an impactful story is to answer the question, “Who is my audience and what is the message I want to share with them?” If the questions are successfully answered, a story can be developed to effectively communicate a central lesson. Stories are also most successful when the audience can identify with the central character/hero of the story (O'Hara, 2015).

This technique of storytelling to communicate is applied to children’s education through the use of educational children’s books. Scientifically accurate children’s books are doubly useful in that they can communicate a life-long moral while simultaneously developing scientific skills. The National Science Teachers Association’s (NSTA) publication, “A Guide to Choosing (and Using) the Best Books for Children”, explains that children only truly learn when they are allowed to construct the information for themselves. It lists the best scientific children’s books as ones that develop the child’s questioning skills, are accurate, and continue to engage the child after the book ends. It also makes the point that for a children's book to be successful in conveying its information it must also be interesting to read (NSTA, 2014).

Annually, the NSTA/Children's Book Council Joint Book Review Panel reviews submitted children's science trade books for the creation of the Outstanding Science Trade Books (OSTB) list. The books are evaluated according to four criteria: illustrations, format/layout and design, genre, and content. The main emphasis of the evaluation is placed on the content of the book. The guidelines for evaluating the content include it being factually correct, free of bias, suited to the age level, and not creating misconceptions about the presented topic (Crowther et al., 2005). The books selected for the OSTB list are widely considered to be the best science trade books available, with great potential to be used within the science classroom.

An example of a book that teaches a moral implicitly through clever storytelling is *A Fine, Fine School* by Sharon Creech (2001). While never explicitly stating the moral, the book clearly communicates that lessons learned outside of school are as important as those learned within. Another prime example of a book that successfully imparts a moral truth to the reader is Dr. Seuss' *The Lorax* (Seuss, 1971). One of the most widely known books focused on sustainability, *The Lorax* showcases storytelling used to teach a moral about consumerism and personal responsibility.

The demand for scientific children's books coupled with the timeless success of *The Lorax* shows that there is a need for more children's books focused on teaching sustainability principles. Understanding the cause and effect nature of consumerism as it relates to the supply chain of a product is a key component to sustainable thinking. As mentioned in the OSTB list criteria (Crowther et al., 2005), the factual accuracy of a scientific trade book is of paramount importance. A modern tool to model the impacts of a product is a Life Cycle Analysis (LCA).

LCA can be defined as a tool for quantifying the impact of products considering its complete life cycle, from the production of raw materials to the final disposal of the products (Goedkoop et al., 2016). LCA's are particularly useful in identifying the inflection points within the life cycle of a product. Inflection points, also known as "hot spots", are the points at which the most significant impacts are incurred. Identifying these inflection points allows for efficient and informed changes to the supply chain to create a desired result.

SimaPro is a software used in impact analysis of products through LCAs. SimaPro includes databases that contain the results of LCAs of various products. For this project, the Ecoinvent v3 database was used (Wernet et al., 2016). The Ecoinvent database consists of well documented process data for thousands of products. A stuffed animal was chosen as the product from the story to analyze.  This was chosen because stuffed animals are common and timeless toys familiar to nearly all children.  The toy was represented as made of four distinct materials; cotton outer-layer, synthetic fiber stuffing, glass eyes, and plastic nose.  These representative materials were chosen because the goal of the LCA for this project was not to create a complete LCA for the toy, but to illustrate the potential impact of the life cycle of a stuffed animal. These materials were assumed to be sufficiently similar to the actual materials used in the production of a stuffed animal to produce an acceptable allegory.

## Methods

### Development of Story

Before I began writing the story, I first conducted research on how to write a successful children's book. I began by interviewing my mother, Leah Cheek, a long time elementary school educator and education consultant with a Masters in Early Childhood development, on what makes a children's book successful. She informed me that the best books have an element of repetition in the phrasing. She also noted that well-written books always have an element of conflict that is then resolved. Finally, she expressed that the moral of a story is best remembered when it is shown implicitly than when it is stated explicitly. I also conducted my own research by reading several children's books, both fiction and non-fiction with the intention of more clearly understanding how these principles are practiced within a story. I made notes on what elements of the stories appealed to me, what books kept my attention and why, and how the scientific books attempted to communicate information. After gathering this information, I began to work on writing my own story.

Early in project, I established the theme of my story to be sustainability in the supply chain. I wanted a story that emphasized both the connectivity of the supply chain, from primary producer to consumer, as well as communicated to children the inherent worth of products in light of the time and energy necessary to create them. Originally my story line focused on the production of a single toy. It traced the toy from the farm where the cotton was grown, to the textile factory where it was woven, etc. until the final product. However, as I continued to develop this storyline, I found that it was difficult to communicate sustainability principles without having them explicitly stated.

During the writing process, I continued to read children's books to inform my own writing. A pivotal book in this process was *A Fine, Fine School* by Sharon Creech (2001). This book served as an example of a story that taught a lesson implicitly through a narrative. Another book that was instrumental in the creation of my own story was *The Lorax* by Dr. Seuss (1971). *The Lorax* also teaches an implicit lesson through narrative, and had a similar theme to my own target, discouraging excessive consumerism. After reading these two stories, I was able to narrow my focus to a singular component of sustainability; in this case, the maxim of "reduce, reuse, and recycle". I switched focus from the production of a singular toy to a narrative exploring the cause and effect of consumerism on a supply chain; specifically, the supply chain for toys. I chose toys as my subject matter because toys are a topic which most children are interested in as well as a product most children consume.

After meeting with Dr. Peggy Ward, my education advisor, who had read and critiqued my story on its effectiveness at communicating my theme and overall readability, I compared my story to the criteria used to evaluate books for the Outstanding Science Trade Books (OSTB) list (Crowther et al., 2005). Although OSTB are also evaluated according to their illustrations and format/design, I only considered the genre and content evaluation criteria, since all I had developed was the written story. Finally, Dr. Ward and I evaluated the success of my book in meeting the Arkansas Science Standards (2016, 2017) (See Appendix C).

## Development of Life Cycle Analysis

The purpose of the LCA portion of this project was two-fold. First, it was intended to give me experience with the development of an LCA, which I had never before performed. LCA is an important tool for biological engineering and this part of the project was specifically intended to help me develop skills relevant to my future career. To perform this LCA I used the software SimaPro. Using SimaPro exposed me to the difficulty in selecting the scope of a project and the myriad of methods of analysis that can be used in an LCA. The second goal was to use SimaPro to model the lifecycle of a stuffed animal to analyze the major impacts of the product and present a high-level, science-based description parallel to my children's book, geared towards the scientific community.

To do this I first had to establish the components of the stuffed animal I was modeling. Initially I planned on modeling an overly simplified version of a stuffed animal, focusing on the production of cotton for the main body of the animal, plastic for the animal's nose, and glass for the animal's eyes. However, after I became more familiar with the SimaPro program, I realized that this was not the best approach. SimaPro contains databases of information of the inputs/outputs necessary for the production of specific products, such as a specific type of plastic instead of just general "plastics". This allows the user to enter specific components to model a lifecycle representative of the actual product. The information that the user must provide is simply the mass of each material needed in the production of the main product. I therefore modified my model to be more representative of a modern stuffed animal. The closest representative LCA's for these materials within the SimaPro Ecoinvent v3 database were polyethylene fleece for the stuffing, woven cotton for the outer layer, polystyrene plastic for the nose, and flat glass for the eyes.

I determined the representative mass of the materials by weighing a medium sized stuffed animal. It was found to weigh 0.272kg. By observing its general structure, I assumed the mass was divided as 85% stuffing, 12% outer covering, 1% plastic nose, and 2% glass eyes. I multiplied these percents by its total mass, yielding 0.231kg polyethylene fleece, 0.033kg woven cotton, 0.0027kg polystyrene (general purposes) and 0.0054kg flat glass.

I used the SimaPro "Assembly" feature to model the assembly of these separate components into the main product, the stuffed animal. I estimated that this assemblage would take 1 kWh of electricity to complete and established this electricity as medium voltage electricity sourced from the North American grid. I then used the SimaPro "Life Cycle" feature to model the life cycle of the stuffed animal. This feature allowed me to enter the assembly I had just created and to add disposal impacts. For disposal, I chose to establish that 100% of disposal was performed through USA curbside pickup. I chose this because it seemed to most closely reflect the scenario I depicted in my children's book.

After creating these scenarios, I conducted two SimaPro analyses; first of the assembly of the stuffed animal and then of the assembly and the disposal of the stuffed animal. The first analysis was intended to show the impacts of each individual component, while the second was intended to give a more complete picture of the product's impact by including a disposal scenario. These analyses required the selection of a method of analysis. There were dozens of different methods to choose from, with each method using a different approach to analyzing the impact of the product. With guidance from Eric Boles, the Director of the U of A Office for Sustainability with a Masters in Biological Engineering, I selected both the ReCiPe 2016 Midpoint (H) and ReCiPe 2016 Endpoint (H) methods. Midpoint impacts are considered the links between the production impacts of a product and the endpoint impacts. For example, in the ReCiPe method of analysis, the production of carcinogenic toxins is a midpoint impact toward the endpoint impact of Human Health.

The ReCiPe 2016 Midpoint method includes 17 different impact categories: human non-carcinogenic toxicity, global warming, land use, fossil resource scarcity, water consumption, ionizing radiation, marine ecotoxicity, human carcinogenic toxicity, freshwater ecotoxicity, terrestrial acidification, fine particulate matter formation, ozone formation impact on terrestrial ecosystems, ozone formation impact on human health, mineral resource scarcity, freshwater eutrophication, terrestrial ecotoxicity, and stratospheric ozone depletion (ReCiPe 2016) (See Appendix B). The Endpoint Impacts are reported as the product's impact on human health, ecosystems, and resources.

For the endpoint impact analysis, the analysis was conducted assuming a product amount of 100,000 units. This was done so that the resulting impacts would be sufficiently large to communicate realistic meaning. The impact of a singular stuffed animal is negligible, but when a larger number is considered the impact is sufficient to demonstrate the effect of large scale production.

## Results and Discussion

### Evaluation of Children's Book

#### Reading the Book to a Class

The first method I used to test the effectiveness of my story (See Appendix A) was to read it to a local group of students within my target demographic. On September 15, 2017, I was invited to Mrs. Brittany Brown's 2nd grade class at Willowbrook Elementary School. I read my story aloud to the class, and afterwards Mrs. Brown led the students in a discussion of what they had thought about the story. When prompted, "Do you have any compliments for Ms. Linden about her story?" several of the students commented that they liked where the story described the specific toys and the part where the characters tried to pass the blame. More importantly, a few of the students commented on how they liked the moral of the story without being told that the story was intended to teach anything. When prompted to express what the moral was in their own words, students responded, "To be content with what you have," "To not always ask for more and to not just want new things," and "To play with the toys you have instead of wanting more". While further investigation would be needed to determine if the class was able to understand the concepts of "recycling" and "reusing" presented in the story, they clearly were able to absorb the implicit encouragement to "reduce". Mrs. Brown also gave her own feedback after the class discussion was over. She claimed that the book kept her and her class engaged throughout the entire story and that she would enjoy incorporating it into her classroom when it became a finished product. Based on this feedback, my story seems to have met my first criterion of success; effectively communicating its theme to the selected demographic.

#### Meeting Arkansas Science Standards

To test the second criterion, meeting established educational standards, my educational advisor, Dr. Peggy Ward, and I compared my book to the Arkansas Science Standards for my target demographic.

(Arkansas Science Standards. 2016) Based on subject matter and word count, my story most closely resembled a book designed for no older than fifth grade. As such, we considered only the standards for K-5 (See Appendix C).

We found that my story met several of the science standards established for Arkansas classrooms. The plot of my story revolved around an investigation of the disappearance of a toy supply; this plot lended itself to several standards which dealt with performing scientific investigations, including gathering information from observations, asking questions, and looking for cause and effect relationships. My story also met the standards that focused on the impact of human activities on the environment. Several of the standards revolved around understanding human impact on the environment and on finding solutions to reduce that impact, both of which were addressed in my story. The science standards also dealt with understanding different materials and the concept that products are made up of separate materials. This is clearly represented in my story. Lastly, the story's representation of a supply chain met the standard of understanding systems as a conglomerate of parts. Reviewing these standards showed that my story met established educational standards and could be incorporated into classroom curriculum, indicating that it was successful according to the second criterion.

## LCA Evaluation

### Impacts of Individual Components

The LCA performed on the assembly of the stuffed animal analyzed what percentage of total impact of the stuffed animal was due to each component of its assembly. For the Midpoint analysis, the components were considered in the unit of one stuffed animal, which was 0.272kg. It was divided as 0.231kg polyethylene fleece, 0.033 kg woven cotton, 0.0027kg polystyrene (general purposes) and 0.0054kg flat glass. 1 kWh of electricity for the assembly process was also considered. For the Endpoint analysis, the components were considered as a unit of 100,000 stuffed animals.

Figure 1 shows that the main three contributors to the impacts of the product assembly were the woven cotton, polyethylene fleece, and process electricity. The flat glass and polystyrene used to make the eyes and nose of the stuffed animal had negligible contribution to the products impacts in each of the categories. This is in part because such a small amount of those components was used, 2% and 1% of the mass respectively, compared to 12% woven cotton and 85% polyethylene fleece by mass.

Cotton was the largest contributor to the overall impact of the product in these catagories: stratospheric ozone, ionizing radiation, fine particulate matter, terrestrial acidification, freshwater eutrophica, terrestrial ecotoxicity, freshwater ecotoxicity, human carcinogenic, human noncarcinogenic toxicity, land use, mineral resource scarcity, and water consumption. The impacts in stratospheric ozone, ionizing radiation, land use, and water consumption were almost entirely due to the woven cotton production. This is significant considering that cotton was only 12% of the total mass of the product. This data alludes to the large environmental impacts of agricultural products. For example, in Table 1, which shows the quantified midpoint impacts of the total product and broken down by component, cotton is the greatest contributor to the categories of both water and land use, both of which are associated with agricultural production. The significance of cotton in the toy's impact shows that it was appropriate to focus on cotton as the main component of the stuffed animal in my story.

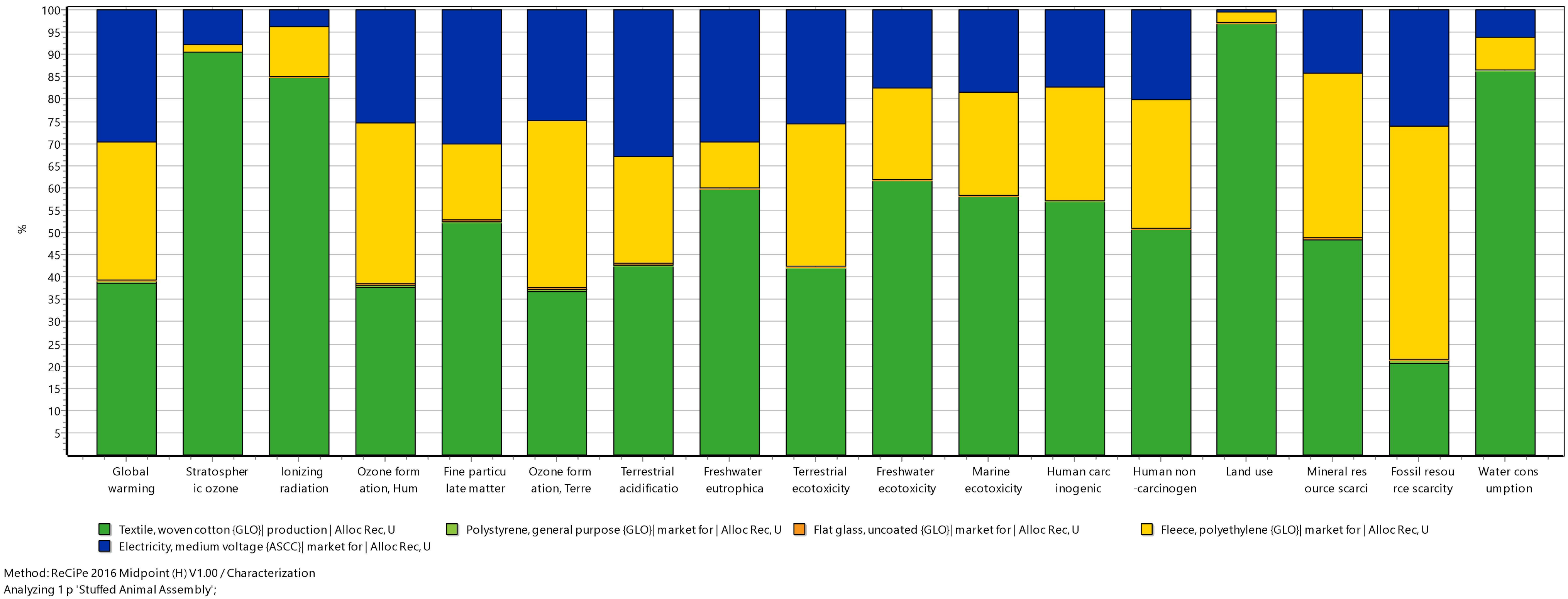


*Figure 1: Midpoint Impact Contribution by Assembly Component*

*Table 1: Quantified Midpoint Impacts of Stuffed Animal Assembly by Component*

| Impact category | Unit | Total | Woven Cotton | Polystyrene | Flat glass | Polyethylene Fleece | Electricity |
|---|---|---|---|---|---|---|---|
| Human non-carcinogenic toxicity | kg 1,4-DBC e | 33.316 | 16.890 | 0.020 | 0.068 | 9.619 | 6.719 |
| Global warming | kg CO2 eq | 2.294 | 0.886 | 0.011 | 0.006 | 0.711 | 0.681 |
| Land use | m2a crop eq | 0.335 | 0.325 | 0.000 | 0.000 | 0.008 | 0.002 |
| Fossil resource scarcity | kg oil eq | 0.860 | 0.178 | 0.005 | 0.001 | 0.451 | 0.224 |
| Water consumption | m3 | 0.089 | 0.077 | 0.000 | 0.000 | 0.006 | 0.006 |
| Ionizing radiation | kBq Co-60 eq | 0.090 | 0.076 | 0.000 | 0.000 | 0.010 | 0.003 |
| Marine ecotoxicity | kg 1,4-DBC e | 0.070 | 0.041 | 0.000 | 0.000 | 0.016 | 0.013 |
| Human carcinogenic toxicity | kg 1,4-DBC e | 0.068 | 0.039 | 0.000 | 0.000 | 0.017 | 0.012 |
| Freshwater ecotoxicity | kg 1,4-DCB e | 0.055 | 0.034 | 0.000 | 0.000 | 0.011 | 0.010 |
| Terrestrial acidification | kg SO2 eq | 0.009 | 0.004 | 0.000 | 0.000 | 0.002 | 0.003 |
| Fine particulate matter formation | kg PM2.5 eq | 0.004 | 0.002 | 0.000 | 0.000 | 0.001 | 0.001 |
| Ozone formation, Terrestrial ecosystems | kg NOx eq | 0.005 | 0.002 | 0.000 | 0.000 | 0.002 | 0.001 |
| Ozone formation, Human health | kg NOx eq | 0.004 | 0.002 | 0.000 | 0.000 | 0.002 | 0.001 |
| Mineral resource scarcity | kg Cu eq | 0.002 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 |
| Freshwater eutrophication | kg P eq | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Terrestrial ecotoxicity | kg 1,4-DCB e | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Stratospheric ozone depletion | kg CFC11 eq | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Table 1 shows that the most significant impact caused by the production of a stuffed animal is human non-carcinogenic toxicity. Figure 2 shows the specific parts of the production process and their contribution to the human non-carcinogenic toxicity impact.

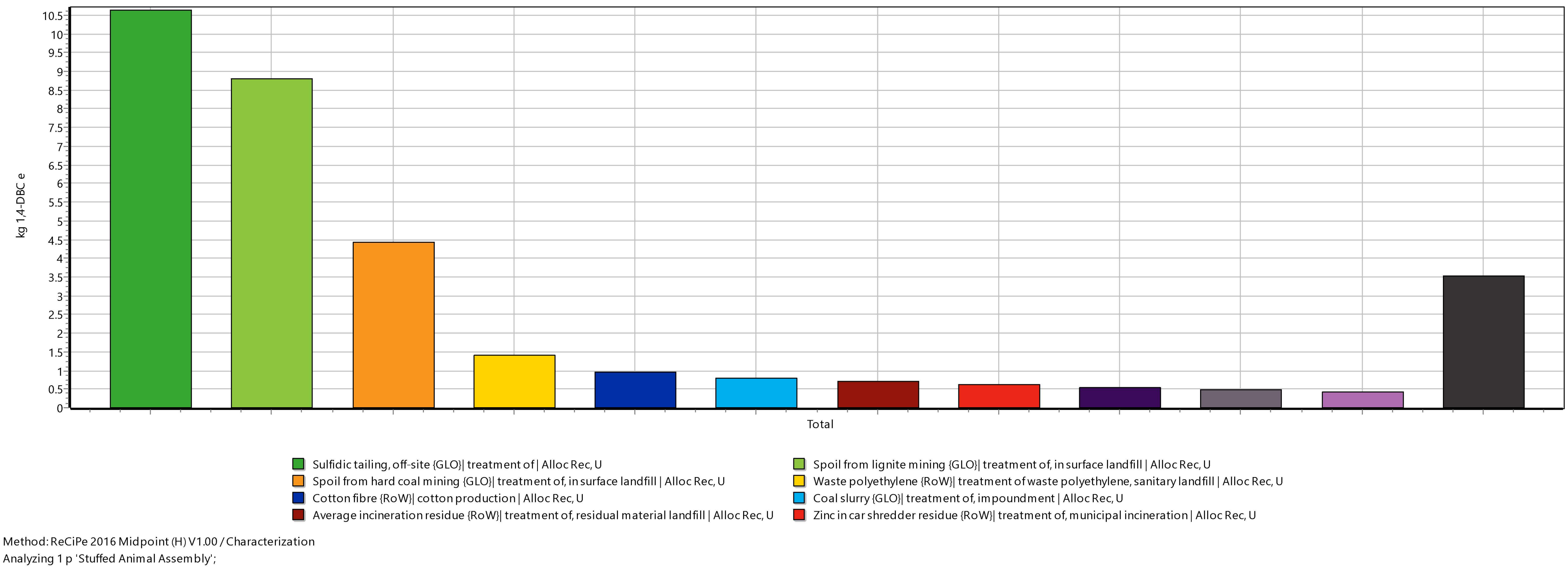


*Figure 2: Process Contributions to Human Non-Carcinogenic Toxicity Impact*

As seen in Figure 2, the first three major contributors to this impact, sulfidic tailings, spoil from lignite mining, and spoil from hard coal mining, are all directly linked to the use of coal to produce the electricity used in the production of the stuffed animal. This impact could be reduced by switching the energy source from coal to a more sustainable and less toxic form of energy, such as natural gas or an renewable energy source. A further LCA could be performed to compare the impact a stuffed animal produced with coal versus one produced with renewable energy.

Figure 3 and Table 2 address the endpoint impacts of the assembly of 100,000 stuffed animals. The three impacts addressed are Human Health, Ecosystems, and Resources. The Human Health impact is reported in units of Disability-Adjusted Life Years (DALY), which is a measure of the cumulative number of years lost due to poor health, disability, and early death (Golsteijn, 2014). The Ecosystems impact is reported in units of species per yr, which is a quantification of the decrease in biodiversity per year ( Huijbregts, 2016). The Resources impact is reported in units of USD2013 resource cost, which is the monetary value of a US Dollar in 2013.

Figure 3 shows that the main three contributors to the impacts of the product assembly were again woven cotton, polyethylene fleece, and process electricity. However, the endpoint analysis provides a clearer picture of the overall impact of the product in that it shows that while cotton causes the main impact in Human Health and Ecosystems, it is the polyethylene fleece that is the greatest contributor to the Resource endpoint impact. Table 2, the quantification of the endpoint impacts, shows that in the category of Resources, the polyethylene represents $18,660.40 in USD 2013 of resource depletion as compared to the $7416.10 necessary to provide 100,000kWh of mid-voltage electricity, or $3,679.40 of resource depletion attributed to the woven cotton.

Table 2 also shows the production of 100,000 stuffed animals has the impact of reducing the human health DALY by 0.5 and has an ecosystems impact of 0.0013 species/yr. The ecosystems impact is such an insignificant value that I did not include the factors contributing to this impact in Table 2.

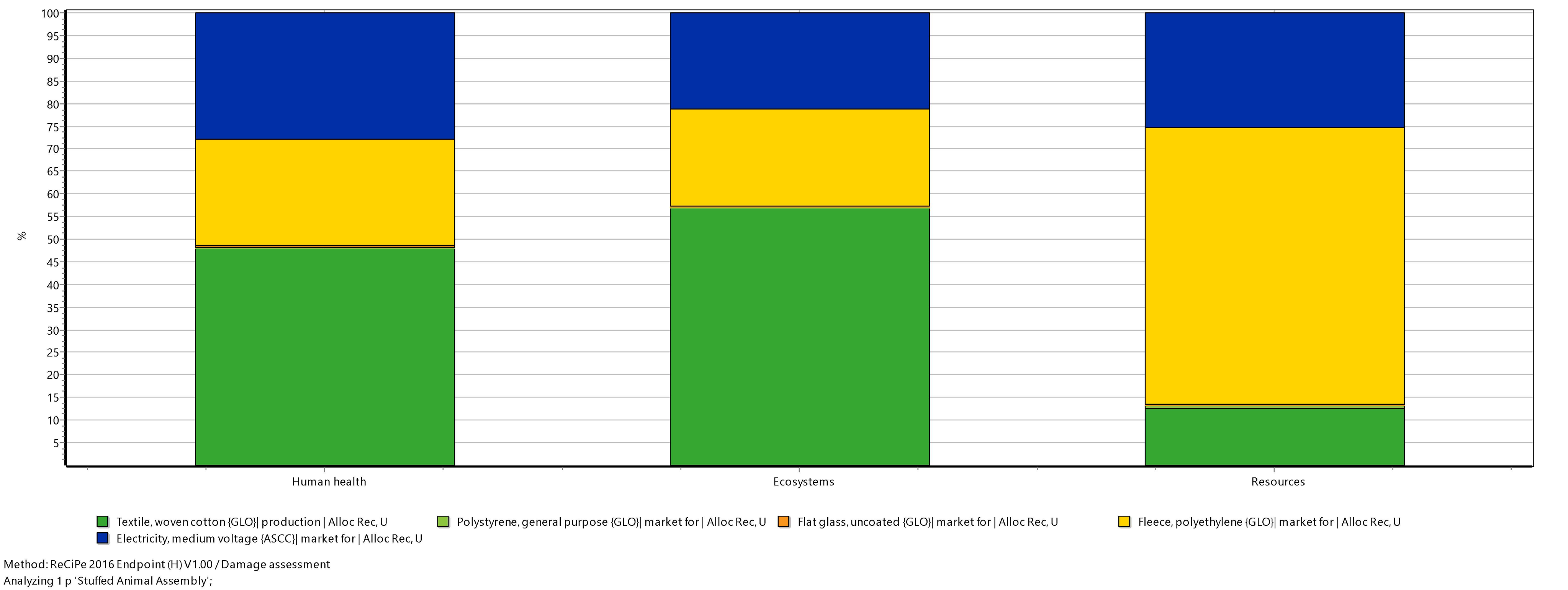


*Figure 3: Endpoint Impact Contribution by Assembly Component*

Table 2: Quantification of Endpoint Impacts of assembly of 100,000 stuffed animals

| Impact category | Unit | Total | Woven Cotton | Polystyrene | Flat glass | Polyethylene Fleece | Electricity |
|---|---|---|---|---|---|---|---|
| **Human health** | DALY | 0.5029 | 0.2412 | 0.0015 | 0.0014 | 0.1183 | 0.1405 |
| **Ecosystems** | species.yr | 0.0013 | 0.0008 | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| **Resources** | USD2013 | 29463.1 | 3679.4 | 205.4 | 50.8 | 18066.4 | 7461.1 |
| Global warming, Human health | DALY | 0.2129 | 0.0822 | 0.0010 | 0.0005 | 0.0660 | 0.0632 |
| Stratospheric ozone depletion | DALY | 0.0002 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Ionizing radiation | DALY | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Ozone formation, Human health | DALY | 0.0004 | 0.0001 | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| Fine particulate matter formation | DALY | 0.2248 | 0.1174 | 0.0004 | 0.0008 | 0.0385 | 0.0676 |
| Human carcinogenic toxicity | DALY | 0.0226 | 0.0128 | 0.0001 | 0.0000 | 0.0058 | 0.0039 |
| Human non-carcinogenic toxicity | DALY | 0.0221 | 0.0112 | 0.0000 | 0.0000 | 0.0064 | 0.0045 |
| Water consumption, Human health | DALY | 0.0198 | 0.0171 | 0.0000 | 0.0000 | 0.0014 | 0.0012 |
| Mineral resource scarcity | USD2013 | 48.2 | 23.2 | 0.0 | 0.2 | 17.8 | 6.9 |
| Fossil resource scarcity | USD2013 | 29414.9 | 3656.2 | 205.3 | 50.6 | 18048.5 | 7454.2 |

Impacts of Disposal versus Assembly

In the second stage of the LCA, I conducted an analysis on the impact of disposing of the stuffed animal. Figure 4 displays the midpoint impacts and shows that curbside disposal of the stuffed animal significantly increases its life-cycle impact in the categories of Freshwater and Marine ecotoxicity as well as human non-carcinogenic toxicity. The increase in human non-carcinogenic toxicity is especially significant, as Table 1 shows that the assembly of the stuffed animal already produced a significant amount of this impact category.

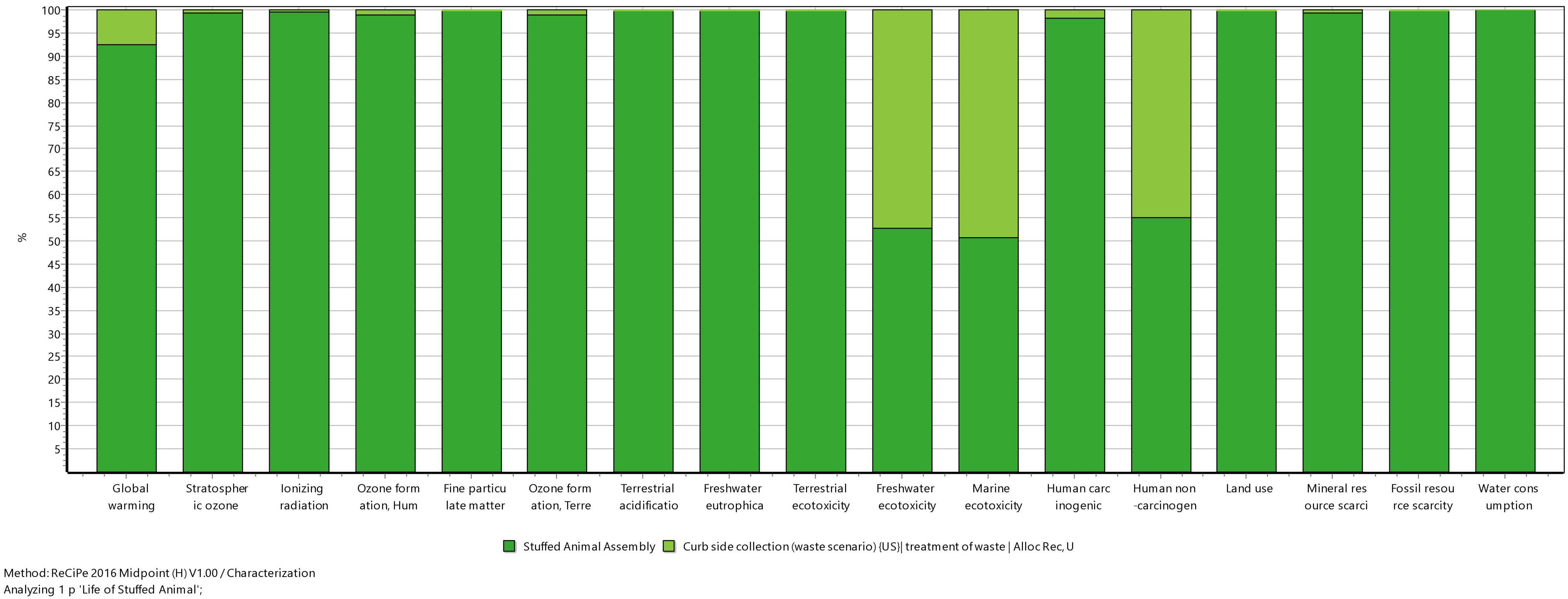


*Figure 4: Midpoint Impact Contribution by Assembly versus Disposal*

## Discussion

The story was shown to be successful in that it met the standards of success that I established at the beginning of the project. Based on the feedback from Mrs. Brown's 2nd grade class after hearing the story, the story met the first standard of effectively communicating the sustainable moral to the intended age demographic. Comparing the story to the Arkansas Science Standards showed that the story accomplished the second standard of meeting established educational standards and that it could be incorporated into current classroom curriculum. Writing this children's book has taught me how to implicitly communicate a lesson through story.

The LCA portion of the project gave insight into the sources of the impacts of the production of a stuffed animal on the ecosystem and human health. The major negative impacts of the production of stuffed animal were all directly linked to the use coal to produce the process energy. These impacts were not only derived from the global warming gases released through production (see Appendix B) but from the toxic emissions linked to their use. These emissions occur both during the harvesting of the fuels and while they are burned for energy. Since the majority of the negative impacts of the production of stuffed animal are directly linked to fossil fuel use, the next step would be to perform an LCA of stuffed animal that was produced using renewable energy sources. It is likely that using a cleaner energy source could significantly reduce the negative impacts of stuffed animal production.

Performing the LCA portion of this project also game me valuable experience with a tool commonly used in biological engineering. I was able to see the complexity of the production process of a common object, a stuffed animal, and to model the impact this production has on the world. I gained experience with SimaPro, the most widely used LCA software, and familiarity with LCA structure. These skills will no doubt prove useful as I advance my career.

## Conclusion

This project gave me a unique opportunity to explore a subject that impacts all people, sustainability, through two parallel tracks targeted at disparate populations: school children and the scientific community. Although they utilized different techniques, both the children's book and the LCA ultimately strove to communicate the message that our consumption comes with a cost. Performing this Honors Project provided me with invaluable experience in communicating with both demographics. I believe I will be able to use these skills to encourage sustainable behavior among these demographics, and possibly many others, as I continue my career.

**Future Opportunities**

An apparent issue with the story that was considered throughout its development was its apparent socioeconomic bias. It was pointed out that the story revolves around children who are able to frequently buy new toys. It was suggested that this might disengage children from a lower socioeconomic background who are not able to buy new toys with any frequency. This seemed a valid point that I should address. After further consideration and discussions with my advisor, Scott Osborn, I believe that this bias may not be significant since the frequency at which the children buy new toys in the story is unrealistic for all but the ultrarich. This over-exaggeration of purchasing hopefully indicates to the audience that the children do not represent a certain group, but are instead a hyperbole of an attitude that could apply to anyone.

One of the main methods of evaluating children's books revolves around the book's illustrations. Before my book could be published and used in classrooms to teach sustainability principles, illustrations will need to be developed. There are many opportunities through the illustrations to further entrench the ideas presented in the book and to meet more scientific standards. For example, within the pages of the story that take place at the toy factory there could be images of blue prints and toy designs that could serve as a further connection between the story and engineering. There is also potential for the illustrations of the recycled toys at the end to encourage sustainable behaviors. I am developing an idea of presenting the toys as "frankentoys", a combination of toys previously featured throughout the book. This would be done to encourage readers to retrofit their own old toys to create new toys.

Another possible way to strengthen the lesson presented in this book would be to include an activity page in the back of the book. This page could challenge readers to "up-cycle" either old toys or even common household refuse into new toys. The page could also include links to "green" toy companies, or even charities that provide for underprivileged children globally. This section of the book would be dedicated to encouraging actions after reading that correspond to the lessons taught through the story.

Additionally, an app could be developed to work in tangent with this book. It could contain designs of toys that could be created from “up-cycling” old toys of other household objects. It could also have the option for children to upload pictures or videos of their own creations along with blue prints of how to make them. An app such as this would not only promote the sustainable behavior introduced through the book, but would create a community, connecting students who are practicing the behavior.

To strengthen the scientific validity of my book, I also plan on including a simplified version of the information I discovered in my LCA. This would look like a simple flowchart of the supply chain of the “soft toy”, i.e. the stuffed animal. It would include the four material components from the LCA as well as the electricity necessary to produce the toy and the consequences of simply tossing out the toy. Each of the materials would be presented with their impact, communicated in terms an average person could understand, such as the global warming potential presented as miles driven by a car.

Further development of the LCA section could include examining the difference in impact of a toy using recycled materials. Since such a significant portion of the toy’s impact came from its cotton component, perhaps switching to a synthetic covering would result in a more environmentally viable toy. This LCA would feature the impacts of a toy made from virgin material to one constructed with recycled material, and perhaps some combination of the two.

This book also has the potential to be developed into a series. Now that the first story has established the sustainability maxim, it would be possible to switch back to my original story design and write about the supply chain of the toys featured in the book. Each story could trace the life cycle of one type of toy, such as the rubber of a bouncy ball or the metal of a model plane. Each of these books could explore how to recycle each of the toys, featuring each of the toys as a character with its own individual book.

It would also be possible to develop this book into a series of sustainability parables. The books could follow children from different communities as they face different sustainability issues, such as equal access to education, pollution of waterways, LID development, or even political involvement.

## Acknowledgements

-Dr. Scott Osborn, for putting up with my annoying creativity and helping my story blossom.

Dr. Peggy Ward, for her enthusiasm and research. For helping me quantify the success of a story.

Dr. Marty Matlock, for critiquing my LCA.

Leah Cheek, for sharing her expertise and experience with children's literature.

Eric Boles, for guiding me in me LCA and teaching me how to communicate the results.

Ben Putman for teaching me how SimaPro works and giving me access to his program. For answering further questions.

Eric Cummings, for introducing me to Ben.

Garn LeBaron, for helping me with my computer troubles.

Linda Pate, for connecting me with Garn.

Brittany Brown and Class, for allowing me to read them my story, and for the constructive feedback.

Ali Ezell, for her encouragement and stress. For keeping me on task by example.

## References


Arkansas Science Standards. (2016). K-4 Science Standards. Little Rock, AR 72201: Arkansas Department of Education. Retrieved from http://www.arkansased.gov/divisions/learning-services/curriculum-and-instruction/curriculum-framework-documents/science

Arkansas Science Standards. (2017). 5 Science Standards. Little Rock, AR 72201: Arkansas Department of Education. Retrieved from http://www.arkansased.gov/divisions/learning-services/curriculum-and-instruction/curriculum-framework-documents/science

Crowther, D. T., Venable, C., Barman, C. (2005). The Making of “The List”: Understanding the Selection Process for the (O)utstanding Science Trade Books list. *Science Scope*., *28(6)* 31-32

Creech, S. (2001). *A Fine, Fine School*. 195 Broadway, New York, NY 10007: HarperCollins.

Goedkoop, M., Oele, M., Leijting, J., Ponsioen, T., Meije, E. (2016). Introduction To LCA with SimaPro, SimaPro.

Golsteijn, L. (2014) Interpretation of Metrics: DALYs And Damage to Human Health. Pre-sustainability. Retrieved from https://www.pre-sustainability.com/news/metrics-interpretation-daly-and-damage-to-human-health

Huijbregts, M.A.J, et al. (2016) ReCiPe 2016: A harmonized life cycle impact assessment method at midpoint and endpoint level: Report I: Characterization. Ruimte en Milieu. Retrieved from: http://www.rivm.nl/bibliotheek/rapporten/2016-0104.pdf

NSTA. (2014). A Guide to Choosing (and Using) the Best Books for Children. NSTA. Retrieved from http://www.nsta.org/publications/ostb/guidetochoosingkidsbooks.aspx

O'Hara, C. (2015). How to Tell a Great Story. Harvard Business Review. Retrieved for https://hbr.org/2014/07/how-to-tell-a-great-story

Pechmann, C. & Reibling, E.T. (2000). Anti-smoking advertising campaigns targeting youth: Case studies from USA and Canada Tobacco Control. *Tobacco Control*. 9:ii18-i31. Retrieved from: http://tobaccocontrol.bmj.com/content/9/suppl_2/ii18

Seuss, Dr. (1971). *The Lorax*. New York: Random House Books for Young Readers.

Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, B. (2016). The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, [online] 21(9), pp.1218–1230. Available at: http://link.springer.com/10.1007/s11367-016-1087-8

Zak, P. J. (2014). Why Your Brain Loves Good Storytelling, Harvard Business Review. Retrieved from https://hbr.org/2014/10/why-your-brain-loves-good-storytelling

## Appendix B: LCA Tables

*Table 2: GHG Impact of Stuffed Animal Assembly*

| Substance | Unit | Total | Woven Cotton | Polystyrene | Flat glass | Polyethylene Fleece | Electricity |
|---|---|---|---|---|---|---|---|
| Total | kg CO2 eq | 2.294 | 0.886 | 0.011 | 0.006 | 0.711 | 0.681 |
| Carbon dioxide, fossil | kg CO2 eq | 1.837 | 0.643 | 0.008 | 0.005 | 0.562 | 0.620 |
| Methane, fossil | kg CO2 eq | 0.283 | 0.082 | 0.003 | 0.000 | 0.146 | 0.051 |
| Methane, chlorodifluoro-, HCFC-22 | kg CO2 eq | 0.069 | 0.069 | 0.000 | 0.000 | 0.000 | 0.000 |
| Dinitrogen monoxide | kg CO2 eq | 0.040 | 0.032 | 0.000 | 0.000 | 0.001 | 0.006 |
| Methane, trifluoro-, HFC-23 | kg CO2 eq | 0.029 | 0.029 | 0.000 | 0.000 | 0.000 | 0.000 |
| Remaining substances | kg CO2 eq | 0.036 | 0.030 | 0.000 | 0.000 | 0.002 | 0.004 |

*Table 3: ReCiPe Midpoint Impact Category Units (ReCiPe 2016)*

| **Impact category** | | **Characterisation factor** | |
|---|---|---|---|
| **Abbreviation** | **Unit*** | **Name** | **Abbreviation** |
| CC | kg ($CO_2$ to air) | global warming potential | GWP |
| OD | kg (CFC-11[5] to air) | ozone depletion potential | ODP |
| TA | kg ($SO_2$ to air) | terrestrial acidification potential | TAP |
| FE | kg (P to freshwater) | freshwater eutrophication potential | FEP |
| ME | kg (N to freshwater) | marine eutrophication potential | MEP |
| HT | kg (14DCB to urban air) | human toxicity potential | HTP |
| POF | kg (NMVOC[6] to air) | photochemical oxidant formation potential | POFP |
| PMF | kg ($PM_{10}$ to air) | particulate matter formation potential | PMFP |
| TET | kg (14DCB to industrial soil) | terrestrial ecotoxicity potential | TETP |
| FET | kg (14DCB to freshwater) | freshwater ecotoxicity potential | FETP |
| MET | kg (14-DCB[7] to marine water) | marine ecotoxicity potential | METP |
| IR | kg ($U^{235}$ to air) | ionising radiation potential | IRP |
| ALO | $m^2$×yr (agricultural land) | agricultural land occupation potential | ALOP |
| ULO | $m^2$×yr (urban land) | urban land occupation potential | ULOP |
| NLT | $m^2$ (natural land) | natural land transformation potential | NLTP |
| WD | $m^3$ (water) | water depletion potential | WDP |
| MRD | kg (Fe) | mineral depletion potential | MDP |
| FD | kg (oil[†]) | fossil depletion potential | FDP |

** The unit of the impact category here is the unit of the indicator result, thus expressed relative to a reference intervention in a concrete LCA study.*
*† The precise reference extraction is "oil, crude, feedstock, 42 MJ per kg, in ground".*

## Appendix C: Relevant Arkansas Science Standards

**Performance Expectations (PEs)**

- **K-ESS3-3** Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.* [Clarification Statement: Examples of human impact on the land could include cutting trees to produce paper and using resources to produce bottles. Examples of solutions could include reusing paper and recycling cans and bottles.]
- **2-PS1-1** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties. [Clarification Statement: Observations could include color, texture, hardness, and flexibility. Patterns could include the similar properties that different materials share.]
- **2-PS1-3** Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object. [Clarification Statement: Examples of pieces could include blocks, building bricks, or other assorted small objects.]

**Disciplinary Core Ideas (DCIs)**

- **ESS3.A: Natural Resources.** Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do. (K-ESS3-1)

- **ESS3.C: Human Impacts on Earth Systems.** Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things. (K-ESS2-2, K-ESS3-3)
- **ESS3.A: Natural Resources.** Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. (4-ESS3-1)
- **ESS3.C: Human Impacts on Earth Systems.** Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1)
- **ETS1.A: Defining and Delimiting Engineering Problems**
    - A situation that people want to change or create can be approached as a problem to be solved through engineering. (2-ETS1-1)
    - Asking questions, making observations, and gathering information are helpful in thinking about problems. (2-ETS1-1)(K-ETS1-1)
    - Before beginning to design a solution, it is important to clearly understand the problem. (2-ETS**1-1)** (K-ETS1-1)
- **ETS1.B: Developing Possible Solutions.** Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (K-ESS3-3) (K-ETS1-2)
- **5-ESS3-1** Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

**Cross Cutting Concepts (CCCs)**

- **Influence of Engineering, Technology, and Science on Society and the Natural World**
  - Every human-made product is designed by applying some knowledge of the natural world and is built using materials derived from the natural world. (2-PS1-2)ETS1.B:
  - Developing Possible Solutions. Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (2-LS2-2)
  - Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (3-ETS1-2)

- **Cause and Effect**
  - Events have causes that generate observable patterns. (2-PS1-4)
  - Simple tests can be designed to gather evidence to support or refute student ideas about causes. (2-PS1-2)
  - Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS2-1, 4-ESS3-2)
- **Energy and Matter.** Objects may break into smaller pieces and be put together into larger pieces, or change shapes. (2-PS1-3)
- **Cause and Effect. Systems and System Models.** A system can be described in terms of its components and their interactions. (5-ESS2-1, 5-ESS3-1)

**Science and Engineering Practices (SEPs)**

- **Constructing Explanations and Designing Solutions**
  - Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.
  - Make observations from several sources to construct an evidence-based account for natural phenomena. (2-ESS1-1)
  - Compare multiple solutions to a problem. (2-ESS2-1)
- **Planning and Carrying Out Investigations**
  - Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.
  - Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question. (2-LS2-1)
  - Make observations (firsthand or from media) to collect data that can be used to make comparisons. (2-LS4-1)

**Nature of Science (NOS)**

- **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena.** Scientists search for cause and effect relationships to explain natural events.(2-PS1-4)