Life cycle assessment of bottled water from Green2O

Dongyan Mu, Ph.D. (PI, Faculty Mentor)

Project Narrative

Scope and Impact

Our analysis on the ENSO-based plastic bottle will cover the entire life cycle and include 'cradle-to-grave' stages from raw material extraction, parts manufacturing, water filling, distribution, to the recycle and disposal in landfills. The same will be done for corn-based bottles as well with focus on analyzing raw material extraction and parts manufacturing as the rest of stages are similar for the two kinds of bottles. The calculations of impacts will be based on manufacturing 1000 500 mL bottles. The scope of the analysis is shown in the figure provided in the project's website (URL: https://sites.google.com/a/kean.edu/dongyan-mu---spf-2015--lca-green2o/).

Impacts considered for analysis in this study include both direct and indirect/upstream impacts. Direct impacts are emissions and discharges directly from the processes in the manufacturing life cycle (the 'process for analysis'). The 'upstream impacts' are the emission/discharges generated in supply chains that provide energy, chemicals and materials to the manufacturing processes. We will assess several impact categories, including fossil fuel use, greenhouse gas (GHG) emissions, eutrophication, acidification, ozone depletion, toxic release, land use and freshwater use that are defined within TRACI 2 (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts) in this study. A popular LCA software package, Simapro 8, will be used to establish the life cycle inventory (LCI) and also present results.

There are multiple benefits of the project. Frist, students involved will get an opportunity to work on a research project in the sustainability area. This will train their skills and expertise in conducting LCA project in a group environment, promote their critical thinking to emerging problems, and cultivate their ability to apply knowledge learnt in class into a real world application. Students will also get a chance to practice Simapro, a preferred skill by many consulting companies in this area. This experience, in this regard, provides professional training to help them obtain internship opportunities and develop their career in this field.

Currently, there is no LCA course taught at the Kean University. The project will also help explore the LCA area within our university. Through the project, a partnership will be established between KU and Green2O, which will improve the influence and outreach of KU in local communities and industries. The success of the project could also potentially lead to more partners from various industries looking into sustainable development. The long-term goal of the project and the Sustainability Science program through interacting with industries is to build a

consulting center that provides services to industries and in return supports research and teaching at the KU.

From the society point of view, this project will promote sustainability of the bottled water industry. Nowadays many people buy bottled water for its portability, convenience, better taste and promised nutrients (e.g., vitamins and electrolytes) added into the water. Admittedly that bottled water is not as environmental benign as tap water, but eliminating the industry is not realistic in because tap water is not able to provide the same functions at least in the short term. This project aims to assess a novel technology that reduces the industry's environmental impacts by producing 100% biodegradable and recyclable water containers. The findings will help provide sustainability implications of the technology, which will lead to recommendations for environmental policies and regulations for the bottled water industry.

Finally, the intellectual merit of this study lays in that it will enrich the literature on LCA and sustainability science. Water is the most important resource for human being. Consequently, drinking water has always attracted interests in sustainability study. Many new technologies for drinking water have been examined with LCA in order to evaluate their environmental viability. However, existing literature on biodegradable bottles manufacturing is still limited, especially LCA investigations of all unit processes in supply chains. This study will fill the gap in this area and also lend reference to similar LCA projects.

Goals and Methods

This LCA study will follow the LCA standards created by the International Organization for Standardization (ISO): ISO 14040 and ISO 14044. Four components will be included in the analysis, i.e. goal and scope, life cycle inventory (LCI), impacts assessment, and interpretation. We plan to achieve four objectives:

Objective 1: Establish LCI of ENSO-based plastic bottles with Simapro.

The study will first establish LCI that includes flows from and to nature for ENSO-bottle manufacturing. For all processes in the scope for analysis, we will analyze the input and output flows of each process to determine the direct resource/energy use and emissions/discharges. The analysis will base on the data provided by Green2O and its suppliers. All process impacts will be the input to Simapro 8. The 'upstream impacts' in supply chains will base on current LCA databases, i.e., Ecoinvent 3.0 and Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model, which provide impact inventories of well-established processes, such as electricity generation, production of additives, and manufacturing of PET. Upstream impacts will be added to direct impacts in the LCI. Simapro 8 has Ecoinvent 3.0 imbedded in it also. We can easily add the upstream impacts into direct impacts.

Objective 2: Establish LCI of corn-based plastic bottles with Simapro.

The method is similar to Objective 1. The inventory for stages of raw material extraction, part manufacturing, and the water filling will be developed in Simapro by process flow analysis. Data for process analysis will be collected from current literature. The inventory for other stages will be based on LCI of ENSO-based plastic bottles that have been established in Objective 1.

Objective 3: examine life cycle impacts of two types of bottles.

The life cycle impact analysis (LCIA) will be conducted for the two types of bottles with Simparo 8 as well. The impact categories will include fossil fuel use (MJ), GHG emissions (kg CO2 eq.), eutrophication (kg PO4-3 eq.), acidification (mol H+ eq.), ozone depletion ( ), land use (m2), and freshwater use (m3). The impacts will be calculated based on productions of 1000 500 mL bottled water.

Objective 4: Interpret results and understand policy implications of biodegradable plastic bottles.

We will interpret the environmental implications derived from life cycle analysis. System uncertainty will be examined and sensitive factors that influence environmental performance of the treatment system will be identified. Sensitivity analysis will be conducted with Simapro 8 as well. The impacts of ENSO-based and corn-based bottled water will be compared. We will also discuss the regulations and policy implications with regard to applying the new technology in the bottled water industry.

Timeline

Phase 1: Establish life cycle inventory (LCI) of ENSO-based and corn-based plastic bottles in Simapro and conduct life cycle impact analysis (06/15/2015- 08/02/2015) (10 weeks)

1. Student training on LCA and Simapro 8. (06/15 - 06/28) (2 weeks)
2. Data collection and literature review. (06/15 – 07/05) (3 weeks)
3. Students and faculty work separately on modeling manufacturing processes in SImapro. (07/06 – 07/19) (2 weeks)
4. Link all processes and establish LCI for two types of bottles. (07/20 –08/02) (2 weeks)
5. Review LCI model in Simapro. (08/02 – 08/09) (1 week)
6. Life cycle impact analysis in Simapro. (08/10 -08/23) (2 weeks)

Phase 2: Data analysis and results dissemination (09/02/2015-12/20/2015)

7. Develop explanation on LCA results and implications. (09/02 – 10/04)
8. Prepare presentations and posters for conferences. (10/04 – 12/20)

Phase 3: Detailed examination and final results dissemination (01/25/2016 – 04/30/2016)

9. Prepare report for Green2O Company. (01/25 – 02/21)
10. Prepare manuscript for publication. (02/22 – 04/30)

Faculty Statement

1. *How will this project benefit your academic career and research agenda?*

Life cycle assessment (LCA) is a widely used tool for system analysis and has been applied by a variety of industries and institutions to evaluate their products or performance with regard to sustainability. LCA complies well with the curriculum of the Sustainability Science Program in SESS and is able to provide broad opportunities to our students in terms of research and professional training. As the first faculty specializes in the LCA area at Kean University, I am collaborating with colleagues in SESS to expand the LCA footprint at Kean. I am teaching several 1000 level courses in SESS now, where I am introducing basic LCA concepts and methodology, and am planning to add a 4000 level LCA course in Fall 2015. The SpF support will provide me a great opportunity to examine and improve my teaching skills. Through guiding and working with students in summer, I can examine my teaching material and methods in current courses so as to better address students' academics needs. The experience I obtained can also help to develop the new course I am planning to teach in Fall 2015. For example, the project could be used as a case study in my LCA classes.

LCA is one of my research areas in sustainability science. My previous research projects focused primarily on biofuels, waste-to-energy, and green products, which are all prevalent sustainability issues today. After joining KU in fall 2014, I decided to continue my research in the above areas, but with more emphasis on the green product area. This is because KU is located in a metropolitan area where manufacturing industries are at high presence. A lot of local companies and business are keen to improve their environmental performance, but are lack of knowledge and expertise in sustainable development. Green2O is a good example: it came to KU for solutions. This project will not only produce presentations and publications but also further develop the network needed for future research.

Finally, through actively interaction with local industries and building my influence in this area, I hope to establish long-term industrial partnerships. This is a good opportunity for me to serve for the communities as well.

2. *How much interaction do you anticipate with your students during the course of the project?*

This project involves interactions between students and faculty at different levels and at different locations. The faculty will first train three students on LCA methodology and assign them to review literature related to bottled water manufacturing. The research group will meet in the faculty's office. At the same time, faculty and students will work together to gather data (mainly process input and output flow data) for establishing the life cycle inventory (LCI). During this period we will visit the Green2O Company, interview the suppliers and review more literature. Afterwards, all three students will work with faculty in the computer lab in SESS to receive training on the Simapro software, and then work on establishing LCI for different scenarios in the project's scope. Process modeling is the major task and will take at least 5 weeks to finish. Each student and faculty will work on one part of LCI and then link all parts together. Following the LCI, we will take 2 weeks on impact analysis in the summer. In fall semester 2015, the research group will meet weekly to analyze, explain, and discuss the LCA results and prepare presentations/posters for conferences in the school year 2015 to 2016. In spring semester 2016, the work will focus on preparing a manuscript that will be published in a peer-review journal. The group will meet once a week to update the project and coordinate the next step.

3. *Provide a specific description of what the students will be doing during this research activity*

Students will take training on LCA methodology and Simapro 8 together in the computer lab in the SESS. They will interview suppliers and review literature together to collect data required for process modeling. Three students will be responsible for different unit processes in the first two weeks of modeling. One will work on modeling ENSO-based bottle manufacturing processes and supply chains. One will work on modeling corn-based bottle manufacturing and supply chains. The third one will work on modeling cap, label and tray manufacturing and supply chains. The faculty will take charge in the rest of processes. Then three students will work together to link separate processes into a whole life cycle for the two bottle scenarios. This is a difficult part and thus is expected to take 3 weeks to finish. After completing the LCI, three students will work together to do impact analysis. All three students are expected to present posters or give oral presentations in conferences. The research group will work on preparing a manuscript for publication together at the end.

Student Statements

1. Describe your preparation or experience related to this project's field of study

[Student 1] Science has always been the one subject in school that captured my attention. The mere idea that there is always more to know, more to learn, more to discover, and more to do has fascinated me all my life. I was always infatuated with the outdoors since childhood. The Boy Scouts of America gave me a love for nature and the beauty it holds. When I entered college, however, is when I discovered that I could help the planet as a career.

I have been involved in a variety of research programs before. I have written research proposals during my time here at Kean University, including one that explores the biodiversity of the coconut crab, as well as a grant proposal that explores the conservation of horseshoe crabs in the Delaware Bay. This past summer I was employed by a company that harvests horseshoe crabs in order to extract their blood for biomedical purposes. As a full time student who was raised in New Jersey, I feel a sense of pride in participating in a research program that explores a company in New Jersey that is trying to do something interesting and worthwhile.

[Student 2] Ever since I was a little girl, my mother had always instilled in me the famous "reduce, reuse, recycle" expression, made famous in the newfangled earth conscious 1970's. Growing up with my mother who was and is to this day an environmentalist and genuine lover of all things terrestrial, I naturally idolized her amazing thought process on preserving our beautiful Earth, and promoting sustainability for all forms of life, everywhere. I am so beyond grateful to have had my mother's influence on the outlook and importance of nature. When I enrolled at Kean University and learned they offered an infant Sustainability program, I knew immediately I had to get on board. Mom's progressive teachings paved the way in which I want to educate myself and others with the importance of living a sustainable lifestyle. So when Professor Mu has asked me about participating in the research project of the Life-Cycle Assessment of bottled water from Green 2O, immediately in was intrigued. Our research will consist of focusing on the energy use and environmental impacts of ENSO-based bottles (a new technology the company Green 2O uses). The study is expected to better our understanding of the new technology Green 2O utilizes, which could hopefully prompt sustainability in the bottled water industry. I believe this research assessment could be the future of how we dispose of water bottles, and could be less of an impact for all the people with a lax attitude towards reducing their carbon footprint.

[Student 3] I have always had an interest in my surroundings. I was always curious to see how, what and why. Growing up I never realized how important the world's resources were. Like some people, they believe resources are limitless. Well one example I believe most people take advantage of is plastic. Learning about the product Green2O has definitely interested in more.

We know plastic does not break down like most organic materials. If anything it can melt or break down, except plastic would leave toxic chemicals. So where does it go? I've learned about the North Pacific Gyre and even elaborated the issues associated with this in my other classes for awareness. From my understanding, the North Pacific Gyre is harboring massive amounts of debris, or garbage, but mostly plastic. Since the gyre has a slow moving current it simply sits there. By the help of heat and the warm ocean issues begin to rise. This is how it can be a limiting factor and harmful to marine life. As debris accumulates we can only assume a positive feedback loop. I began to question why do most people not hear about this? Yet we still consume and dispose.

My major is Sustainability Science and I believe that small steps can lead to a better future. It is a part of the mission for sustainability. Therefore, I know the Green2O water bottle is definitely a small step that can have a huge impact on recycling. From what I've learned in my Sustainability class, using Life Cycle Assessment helps identify and analyze the input and outputs from a product. We use models to gradually improve the product as well as knowing how to do it in the most sustainable way. Therefore, Green2O is an amazing project to base our Life Cycle Assessment on. The amount of resources and emissions used to design the Green2O bottle would have to include energy, water and transportation use, which are one of the few examples we would include in our evaluation. Not only do I want to be a part of this project for learning experiences but I want to advance my knowledge in using the Life Cycle Assessment. This project has a positive impact on society and applying what I've learned can only take us to the next step. The work that I will contribute, along with my colleagues and Dr. Mu, can be a challenge but a challenge I will be willing to progress in.

I'm eager to make environmental approaches and use simulation models to interpret and assess resources used to produce Green2O. I know how important it is in terms of ecological and public health purposes. Therefore, I would love the opportunity to use our resources for this research to introduce and educate the public, especially young children, about the impact this product can have. For example, universities are one of the biggest factors for having a large ecological footprint in the United States, mostly because universities consume and demand plenty of resources and materials, one of them food. If Green2O is introduced and exposed of the efforts into making this product sustainably, then it will not only support the product itself but will be beneficial. It is a small step in reducing part of the nation’s ecological footprint.

2. How will this project enhance your learning and career goals?

[Student 1] Participating in this research program will further benefit my education by allowing me to grow my skills as a scientist. It will bring me great satisfaction in working on a project that

could benefit the planet and great happiness to work with my peers. I hope for it to be an amazing experience that I can draw on and remember fondly in the future. It could also help me further my education by standing out on a Graduate School application. I would feel honored and humbled to be able to be involved in this research program.

[Student 2] Participating in such a progressive research project will not only fulfill my undying need for substantial change in an industry that dominates the world's way of manufacturing and drinking bottled water, but also morally will affect my psyche on being a part of something that I undoubtedly believe that could radically shape the future of the bottled water industry and more importantly, environmentally. We are all as humans apart of mother Earth, and every action we make towards 'her' affects everything that inhabits this world. I am sure that this opportunity will enhance my education to the fullest extent, and guide me towards a bright future in the science world.

[Student 3] As one of my future goals, I do want to consult. My focus is on expanding my research to find sustainable approaches in developing countries. From what I will take in this research can only lead to advancements in the future. The impact this research has will be a small step but a step closer to more sustainable efforts that I cannot wait to take part in. Therefore, my focus on this research is to work with my colleagues and Dr. Mu by the use of models and determine the input and output to be resource efficient. I want to use, as well as improve, my knowledge of life cycle assessment approaches in this research. The result of this can only be to move forward, possibly even help reduce debris, especially plastic in gyres.