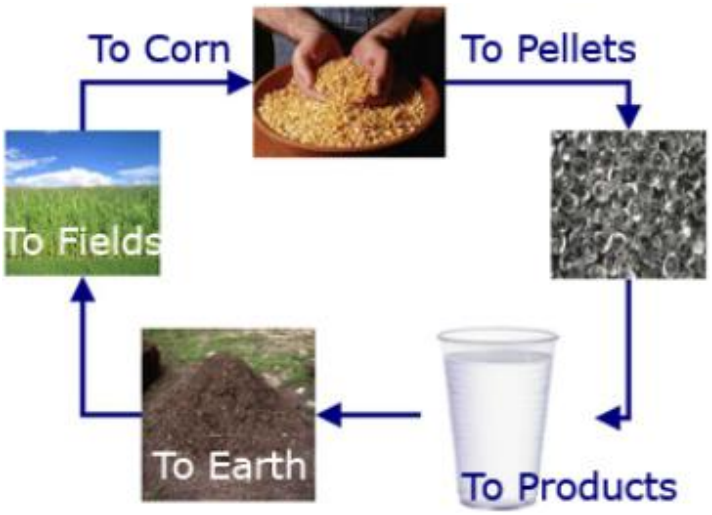
Last month, I went to a coffee shop near campus. The iced latte came in a plastic cup that was labeled: "Greenware/100% Annually Renewable/Eco-Friendly Packaging." On the other side, it said, "This environmentally sustainable cup is made entirely from plants." Well, "that's nice," I thought. Innovations are being made to make everyday products environmentally friendly. When I went to throw out the cup, I couldn't decide between throwing it in the "plastics" bin or the regular garbage bin. If it's made out of plants, then it should go in the regular bin. But, it feels like plastic and it is doing the job that a plastic cup would do. So, which bin does it belong in so I can appropriately discard it? Realizing and feeling a bit foolish that I am spending too much time on the issue, I threw it in the plastics bin. It was not until I did my research that I realized I made the wrong choice.

GreenWare cup made from NatureWorks' polylactide biopolymer

NatureWorks LLC, owned by Cargill Dow LLC, produces unique biopolymers, polylactide resins (PLA). These biopolymers are derived from corn and are used to make plastic products, unlike conventional plastics that are derived from petroleum. According to the company, "If all PET [polyethylene terephthalate, currently the most common resin used to make plastic] beverage bottles made from crude oil sold today in the U.S. were made from polylactide plastic, Americans would save the equivalent of 1 billion gallons of gasoline a year."[1] Not only are consumers being environmentally-friendly when they buy plastics made from PLA, they are being patriotic. Corn is an annually renewable resource. The corn that is used for biopolymer production is planted, harvested, and transformed in the heartlands of America: Blair, Nebraska. Not only that, corn beats petroleum when it comes to price stability. In terms of politics,

[1] Mans, Jack. "New Water Bottle is Made From Plants." Packaging Digest Sept. 2004: 92-93.

according to Newmann's Own CEO Peter Meehan, "No one has ever gone to war over corn."[2] So, is there any downfall to this great innovation?



NatureWork's PLA sustainability concept

Several Life Cycle Analysis have been made on biopolymers and petroleum-based plastics. Each study, however, made numerous assumptions on the production of biopolymers and lack material and environmental-impact data when it comes to the analysis of PLA. This is probably because the acknowledgement and growth of PLA is fairly new and the company does not want to share important information that might be advantageous to their competitors. Consequently, the most comprehensive PLA Life Cycle Analysis was commissioned and researched by Cargill Dow LLC.

A simplified life cycle analysis for PLA and petroleum-based plastics can be seen in the following diagrams.

[2] Royte, Elizabeth. "Corn Plastic to the Rescue." Smithsonian Magazine Aug. 2006.

Life Cycle Analysis of PLA

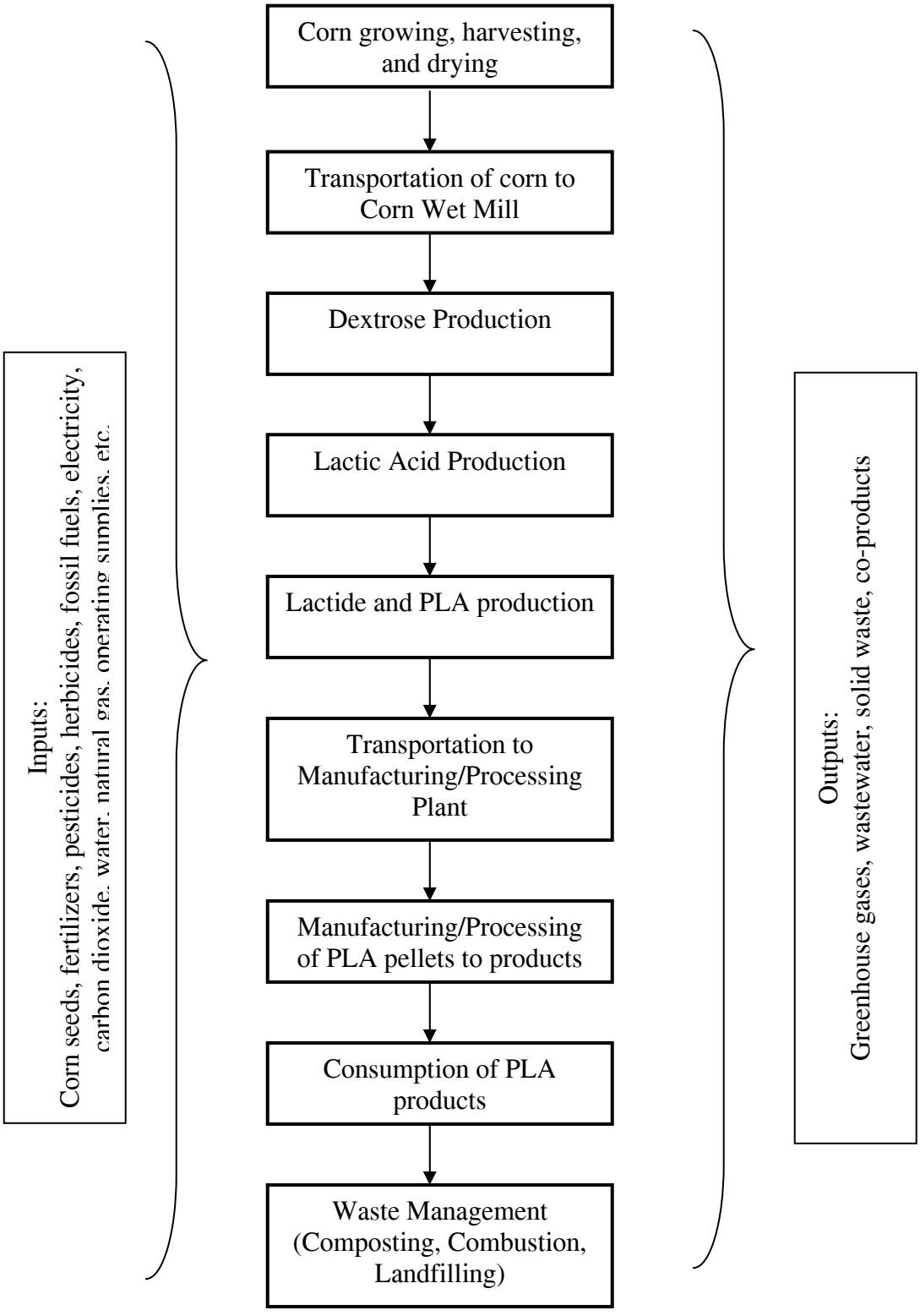


Diagram is composed from: Vink, Erwin. "Applications of Life Cycle Assessment"; Bohlmann, Gregory. "Biodegradable Packaging"

Life Cycle Analysis of Petroleum-based Plastics

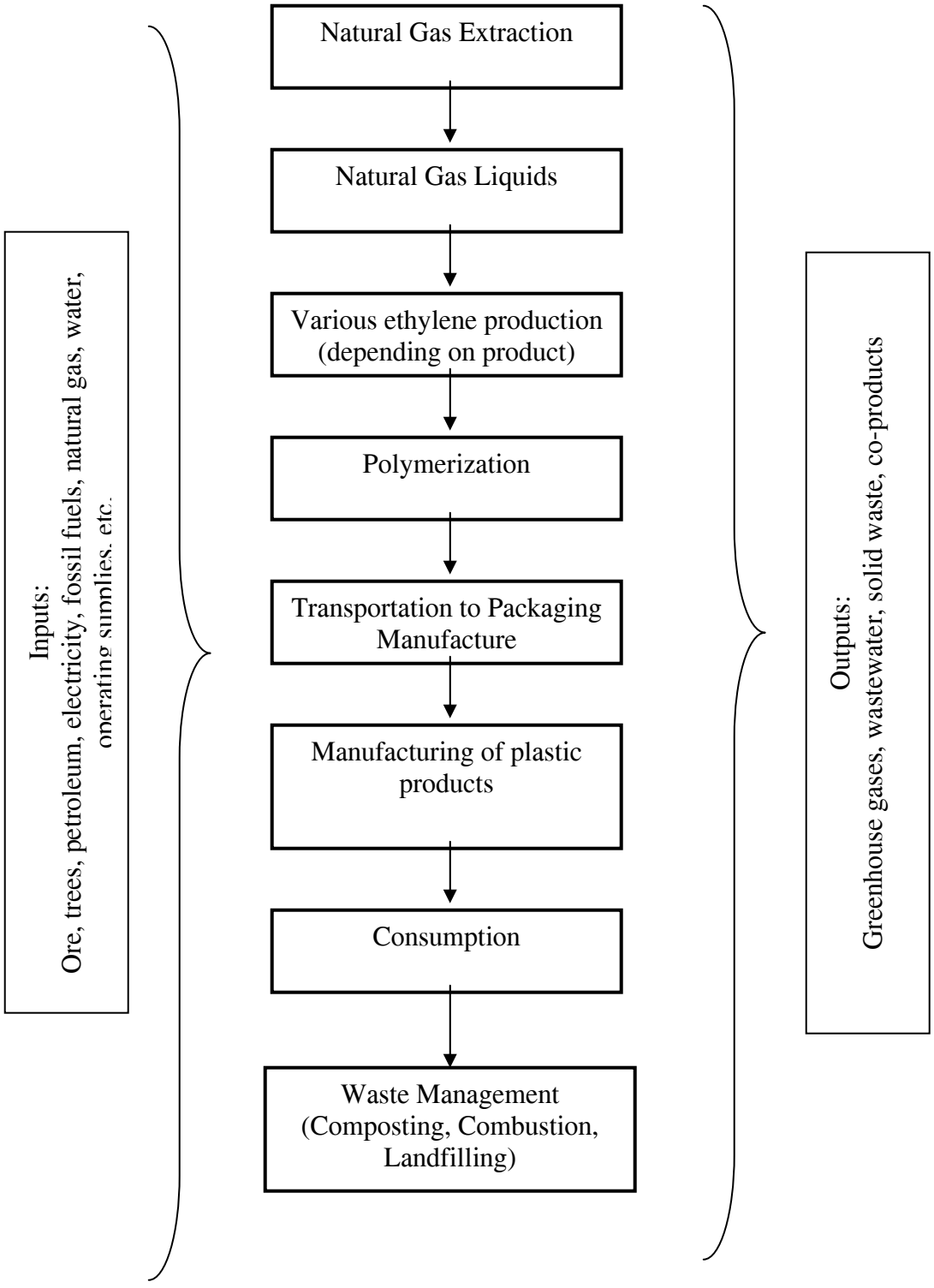


Diagram is composed from: Bohlmann, Gregory. "Biodegradable Packaging"

In the energy consumption category, studies have shown that PLA is more sustainable (this includes the energy used to harvest and process the corn into resins). In the cradle-to-gate life cycle of PLA pellets, "polylactide production system uses 25-55% less fossil energy than the petroleum-based polymers."[3] The sustainability changes depending on what the PLA products are made into. For envelope window films, PLA-based films use more energy than petroleum-based films. This is due to the extra drying step and higher amount of content needed for the PLA films.[4] Also, transportation of the resins amounts for about 6 percent of the total energy used. Since NatureWork's PLA melts at a low temperature, it is suggested that the resins be kept below 105 degrees Fahrenheit. This meant that refrigeration trucks might be needed to transport the resins during the summer months if the products are going to southwestern U.S. Nevertheless, PLA still beats conventional plastic resins when it comes to energy sustainability. According to Athena Institute's study, for PLA products, 50 percent of the energy used comes from fossil fuels. For petroleum-based resins, however, the percentage is more than 89 percent.[5]

There is a lack of research on water uses for the production of PLA and petroleum-based resins. The data provided by Gargill Dow shows that overall PLA uses less water than most of the petroleum-based resins. Most of the water is used for crop irrigation. For conventional plastics, most of the water is used to cool the products. The end result for conventional plastics can be acidic and even toxic water. The end result for PLA plants is agricultural runoff, since the crops are being treated with nitrogen fertilizer, pesticides, and herbicides.[6] Which is more socially and environmentally viable? There is no straight or quantifiable answer.

The Life Cycle Analyses also look into greenhouse gas emissions, over a course of a century. There is no clear evidence of which kind of plastic emits fewer gases during decomposition. The way that PLA materials and petroleum-based materials are discarded affects the amount and type of greenhouse gas emissions. For composting, carbon dioxide is stored in the closed system, that is if the product is composted in an optimum environment. Gas is

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[3] Vink, Erwin, et al. "Applications of Life Cycle Assessment to NatureWorks Polylactide (PLA) Production." Science Direct
[4] Franklin Associates. "Life Cycle Inventory of Five Products." Athena Institute International: 6.
[5] Franklin Associates. "Life Cycle Inventory of Five Products." Athena Institute International: 7.
[6] Franklin Associates. "Life Cycle Inventory of Five Products." Athena Institute International: Forward.

bounded into the petroleum-based plastic cup and is not released into the atmosphere.[7] However, this means that it will not decompose for more than a century. For PLA, it requires about 140 degree Fahrenheit with humidity between 80-90% for decomposition to take place. It then takes about 47 days for a PLA cup to be broken down into carbon dioxide, water, and humus.[8] Therefore, people are advised not to throw PLA products into their backyard compost, as the product will not biodegrade in that environment. In a landfill, methane gases are released while carbon gases are stored in the ground. This is true of petroleum-based plastics if they are in the landfill for over a hundred years. Few studies have been done on greenhouse gas emissions of biodegradable polymers to be applied to PLA products.[9] As for combustion of conventional plastics, carbon dioxide and other compounds are emitted. If not done in an optimum manner, the combustion of conventional plastics may also release carbon monoxide and other toxic gases. Combustion of PLA products will produce the same amount of carbon dioxide as the incineration of petroleum-based plastics. The difference is that PLA's carbon dioxide is from biomass (the corn that was used to make PLA took carbon dioxide in from the air to feed its photosynthesis). Therefore, the return of the gas "is part of a natural cycle and would not be viewed as a contribution to increased greenhouse gases."[10] It seems that scientists view PLA materials more sustainable than conventional plastics based on greenhouse gas emissions. However, they won't necessarily sign their names to that statement.

PLA products are currently viewed as unsustainable when it comes to post-consumer solid waste. This is largely due to the lack of infrastructure to collect and recycle the PLA material. PET and other petroleum-based plastics have the advantage of having numerous nationwide facilities that readily accepts and recycles these materials. These facilities cannot process PLA and is viewed as contaminants because of its low melting point. It is believed that "large amounts of PLA can interfere with conventional composting because the polymer reverts into lactic acid, making the compost wetter and more acidic."[11] Recycling facilities worry that if too much PLA is dumped at their sites, they will have to pay to have the materials sorted out and

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[7] Franklin Associates. "Life Cycle Inventory of Five Products." Athena Institute International:13.
[8] "A More Responsible Alternative " NatureWorks LLC.
[9] Bohlmann, Gregory. "Biodegradable Packaging." Environmental Progress: 345.
[10] Franklin Associates. "Life Cycle Inventory of Five Products." Athena Institute International Forward.
[11] Royte, Elizabeth. "Corn Plastic to the Rescue." Smithsonian Magazine Aug. 2006.

disposed of. An estimation of one PLA bottle in 1000 PET bottles to 4 percent of PLA bottles in a PET load are needed to contaminate the recycling facility.[12] NatureWorks reassures that such a scenario will not happen since they are not producing enough biopolymers to cause such havoc. The company identified 113 composting facilities that would accept PLA materials; some "handle industrial food-processing waste or yard trimmings, others are college or prison operations -- but only about a quarter of them accept residential foodscraps collected by municipalities."[13] It seems that at the moment, it is best if consumers throw away their PLA products along with their regular trash and hope that it goes to one of the facilities that accepts PLA materials. NatureWorks is currently working with some local governments to figure out a more accessible recycling system for PLA. They are also looking to convert their composters to anaerobic digesters, which will allow the material to biodegrade without oxygen. The methane gas that is released will be captured and used for fuel.[14]

The commercialization of biopolymers is still in its infancy. Although it is based on a goal towards sustainability, it still has limited uses. Currently, it is used for juice, dairy products, and bottled water. It doesn't work well with beer or soda because the material "still lacks the gas and moisture vapor barrier properties of PET...milk and water bottled in NatureWorks PLA typically leave the shelf in 7 to 10 days."[15] For John Delfausse, vice president of packaging for beauty product maker Aveda Corp, "the company needs up to three years of shelf life for some of its products, and PLA containers haven't held up."[16] Prices for PLA resins have always been higher than petroleum-based resins. In recent years, its prices have decreased. The decrease is not enticing enough for the processing companies to buy the biopolymers since they need to add the "cost-increasing additives to improve PLA's properties."[17] There is an increasing interest for biopolymers, but companies are not committed to them until they see major improvements in its durability and versatility. Until such innovations in the biopolymer industry emerge, consumers will have to rely on petroleum-based plastics, which currently may just be a bit less sustainable than PLA products.

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[12] Learn, Scott. "New Plastic, Second Thoughts." The Oregonian 24 Oct. 2008.
[13] Royte, Elizabeth. "Corn Plastic to the Rescue." Smithsonian Magazine Aug. 2006.
[14] Royte, Elizabeth. "Corn Plastic to the Rescue." Smithsonian Magazine Aug. 2006.
[15] Kaplan, Andrew. "After PET?" Beverage World 15 Mar. 2005.
[16] Truini, Joe. "Recycling A New Plastic." Waste News 12 Sept. 2005.
[17] Renstrom, Roger "Bioplastic Makers Look For More Commitment." Plastic News 20 Oct. 2008.

Some environmentalists express their concerns on using potential food or land for food for plastic production. NatureWorks is looking for ways to use less corn to produce targeted production amounts. MicroGREEN Polymers came out with a microcellular expansion technology. Essentially, this technology will enable "converters and manufactures to make more product with less source plastic by controllably expanding solid-state polymers with billions of microscopic cells within its structure."[18] This will help biopolymer companies, like NatureWorks, to reduce the cost and weight of plastic products, and still have them functioning well. NatureWorks is also looking into replacing corn with switchgrass and other crops that doesn't require a lot of irrigation. They are also researching the possibility and sustainability of using corn residues (50% of dried corn is residue, also known as "stover," and is usually left in the field as fertilizer) to create energy and biopolymers.[19] It is no doubt that NatureWorks is listening to their clients and is researching ways to create a more sustainable life cycle for its products.

The most seemingly easy solution to the plastics sustainability issue is for consumers to become less wasteful. For consumers who live in a rich aquifer areas, stop buying bottled waters and drink from the tap. Bring your own flask to the coffee shop. Of course, this is a very idealistic solution. Most Americans have become wasteful through years of practice. So, lucky for biopolymers, its future seems hopeful as consumer habits seem to remain wasteful and petroleum is becoming scarce. Although the conventional plastics makers are relying on recycling as a major part of their sustainable design, they cannot discard the fact that their products derive from non-renewable sources. Perhaps petroleum-based plastics will slowly be phased out as new innovations make biopolymers more applicable to different industries. PLA already has a good rapport with consumers based on its concept of using renewable resources and its product's biodegradability. However, biopolymers are facing an uphill battle when it comes to winning the hearts of manufacturers and waste facilities. More research is needed to improve the products as well as the infrastructure to maintain the sustainable design of the biopolymer. Investment in recycling education for the public is needed, so people know how to properly dispose their plastic materials. This way, the consumers won't be the ones that mess up the sustainable concept of biopolymers and recycled biopolymers.

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[18] "MicroGREEN Polymers Unveils Sustainable Technology." Business Wire 11 Nov. 2008.
[19] Dornburg, Veronika. "Comparing the Land Requirements." Journal of Industrial Ecology: 94.

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Image of GreenWare cup: http://dgs.greenhome.com/products/restaurant_supplies/food_service/115028

Image of NatureWork's PLA Cycle: http://www.biosmartpackaging.com/sitebuilder/images/PLA-Cycle2-362x261.jpg