MODULE

1

GRADES 6-8

Sustainable Polymers

Taking Action to Solve the Challenge of Plastics

A 4-H STEM Curriculum for Grades 6-8

National Science Foundation

NSF Center for Sustainable Polymers

4-H Polymer Science Curriculum for

Grades 6-8

4hpolymers.org

The themes of these modules touch on the prevalence and impact of plastics in everyday life. Plastics are versatile materials that come in different shapes, sizes, and exhibit different material properties. Scientists and engineers are working on new ways to create, use, and recycle plastics, so we can use plastics for their many advantages and lessen their effects on our environment.

Each module will include "Tips for Facilitators" as well as opportunities to use "I Wonder" Boards, science journals, and math. In addition, these modules incorporate the SciGirls Strategies for gender-equitable STEM learning. We encourage instructors to collect feedback throughout this module and submit via this evaluation form: 4hpolymers.org/evaluation.

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Tips and Callouts

"I Wonder" Boards

These boards should be used to track youth questions and ideas during the lesson for further investigation. This tool promotes experimental learning by youth while encouraging curiosity and discovery. Basic "I Wonder" Boards have "I Wonder..." written at the top of a large sheet or white board.

Science Journals

Journals help youth keep track of what they've noticed and learned during the activities. Journals promote a science identity and allow youth to reflect on their thoughts and feelings.

Using Math

Providing youth opportunities to use math and numbers is important for developing their math skills at a young age. Math is important to science because it allows definitive answers to be found and can help youth find out if something has changed.

Science and Engineering Practices

The Next Generation Science Standards (NGSS) identify eight practices of science and engineering practices that are essential for all students to learn. These practices are what youth do in order to make sense of phenomena and reflect the major practices that scientists and engineers use to investigate the world and design and build systems.

SciGirls Strategies

Based on educational research, the SciGirls Strategies are used to target and engage girls in STEM learning but have also been proven to work with all learners, including underrepresented youth. See the SciGirls Strategies handout at the back of the module for a more detailed explanation.

Module 1

The Plastic Past: Rise of the World's Most Popular Material

Driving Questions:

- **Why have plastics become one of the most utilized materials in the world?**
- **What are some environmental impacts of plastics and alternative materials such as aluminum and glass?**

Introduction

MODULE SUMMARY

Youth will prepare and deliver a marketing pitch to a fictional beverage company for a beverage container made from their assigned type of material (plastic, aluminum, or glass) using scientific information. Afterward, youth will reflect as a large group on the advantages and disadvantages of each type of material. The questions they ask and explanations they develop will help guide them toward a youth-driven action project of their own design.

Time Required: 2+ meetings depending on youth-driven action project

- Set up for activity: 10 minutes
- Polymer Science Inquiry activity: Pitch Your Material (75-110 minutes)
- Youth as Change Agents activity: Youth-driven projects (varies, 60-120 minutes)

Module Focus

LEARNING OBJECTIVE(S)	• Youth will explore the history of plastics, glass, and aluminum use. • Youth will interpret data as they pertain to the environmental impacts of different types of packaging and other plastic products. • Youth will describe strategies to mitigate the effects of packaging and other types of materials in their homes and communities.
SCIENCE & ENGINEERING PRACTICES (NGSS) 2	• Engaging in argument from evidence. • Analyzing and interpreting data. • Constructing explanations and designing solutions.
CONCEPTS & VOCABULARY	• **Aluminum**: a silvery-white, lightweight, non-magnetic metal. • **Carbon footprint**: the amount of carbon dioxide produced due to the consumption of fossil fuels through human activities (e.g., transportation, electricity generation, agriculture, manufacturing). • **Change agent**: youth leaders who transform their ideas into actionable projects to create positive social impact. • **Disposal**: the action or process of throwing away or getting rid of something.

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Support as they investigate using STEM practices

Module Focus (Continued)

CONCEPTS & VOCABULARY	
	• **Glass**: a hard, brittle substance made from sand. • **Landfill**: site where waste from the community is taken. • **Life cycle**: the extraction of raw materials; manufacturing of the product; the transportation of the product; the use of the product by the consumer; and the disposal or recovery of the product. • **Plastic**: a type of material made from polymers that can be molded into solid objects. Usually made from petroleum/oil. • **Recycle**: process of converting waste materials into new objects. • **Trend**: a way of demonstrating change over time.

Facilitator Preparation

MATERIALS NEEDED

- ☐ Copies of Appendix A-1 (blank life cycle handout); one per group.
- ☐ Copy a set of life cycle cards from Appendix A-2 ; one set per group.
- ☐ Copies of Appendix B (historical graphs of plastic, aluminum, and glass usage and recycling); one for each group.
- ☐ Copies of Appendices C-1, C-2, and C-3 (material information sheets for plastic, aluminum, and glass); one per group.
- ☐ Flip chart paper and markers

GETTING READY

- Cut out life cycle cards from Appendix A-2.
- Print copies of handouts for each pair/small group.

YOUTH AS CHANGE AGENTS

- ☐ Flip chart paper
- ☐ Markers
- ☐ Copy of Change Agent Approach Matrix - see Front Matter Facilitation Tools

YOUTH AS CHANGE AGENTS

- Review Change Agent Approach Matrix in Front Matter Facilitation Tools
- For tips on supporting open discussion and collective decision making, see Front Matter Facilitation Tools for active group facilitation strategies.

Background Information for the Facilitator

For thousands of years, people have used various containers to store beverages. The types of materials used to make these containers have varied depending on the availability of **raw materials** and cultural traditions. Over time, new types of materials have been developed and often replaced previous ones. For example, glass containers were replaced by aluminum containers. The production of glass from sand, and the weight of glass to transport, created a large **carbon footprint**; aluminum was much lighter and easier to transport.

The history of plastics began over 3,500 years ago. One of the first documented uses of natural plastic comes from a Pre-Columbian civilization's ceremonial ballgame, which used a ball made from latex of rubber trees wrapped around horns and shells. It was not until the 20th century when plastic use became more common *(Quinn et al., 2013)*. Although some discoveries in the 1800s (e.g., vulcanized rubber; polystyrene) were precursors to the plastics we know and use today, it was the beginning of the 1900s that brought the "plastic age." Because of the versatility of plastics, the new "plastic age" was heralded with much enthusiasm:

> *It is a world free from moth and rust and full of colour, a world largely built up of synthetic materials made from the most universally distributed substances, a world in which nations are more and more independent of localised naturalised resources, a world in which man, like a magician, makes what he wants for almost every need out of what is beneath and around him.* (Yarsley & Couzens 1945, p. 152)

During World War II, plastics took a central role in military use, heralding a "plastic revolution." Starting in the 1950s, plastic producers shifted to the consumer market, embarking on a massive public campaign to win consumer hearts and minds with new products like Tupperware, Formica tables, Fiberglass chairs, Naugahyde love seats, hula-hoops, disposable pens, silly putty, and nylon pantyhose. By 1960, the use of plastic surpassed that of aluminum. The adoption of plastics by society for a wide variety of common uses may have occurred because of their functional and adaptable properties. Plastics are inexpensive, lightweight, strong, durable, corrosion-resistant materials, and have high thermal and electrical insulation properties. The diversity of polymers and the versatility of their properties allow them to be used to produce a vast array of products that have myriad societal benefits.

Key Events in the History of Plastics

A timeline of some key events in the history of plastics (e.g., Quinn et al., 2013; University of Oregon, 2020):

1839

1839
Charles Goodyear modernized vulcanized rubber.

Eduard Simon discovered polystyrene.

1869
John W. Hyatt made celluloid, the first commercially successful plastic product

1872
Eugen Baumann discovered polyvinyl chloride (PVC).

1907
Leo Baekeland creates Bakelite, the world's first synthetic plastic.

1908
Jacques Brandenberger invented cellophane.

1940

1941
Researchers from Dow's Chemical Physics laboratory produced polystyrene, more commonly known as Styrofoam.

1940s
Plastics become central in military supply chains for helmets, goggles, raincoats, tents, parachutes, etc.

1950s
Plastic manufacturers begin large marketing campaigns directed at consumers.

1960

1960
The production of plastic surpasses aluminum.

1960s
HDPE plastic bottles introduced and replace most glass bottles

1960

2000

2020

1960s
Polyester becomes the least expensive type of cloth and becomes the most commonly used fabric in clothing.

1965
Kevlar developed at DuPont by Stephanie Kwolek.

1973
Nathaniel Wyeth patented polyethylene terephthalate (PET) plastic. PET bottles were designed to withstand the pressure from carbonated drinks.

1977
Plastic bags are introduced to the grocery industry as alternatives to paper bags.

1988
The Resin Identification Code was invented by the Society of the Plastics Industry.

1988
First plastic money issued in Australia.

2008
China bans plastic bags.

2012
San Francisco becomes the first city in the United States to ban plastic bags.

2014
California became the first state in the United States to ban single-use plastic bags in stores. Today, stores charge a 10-cent fee for single-use plastic bags and paper bags.

2018
Seattle became the largest U.S. city to ban plastic single-use straws.

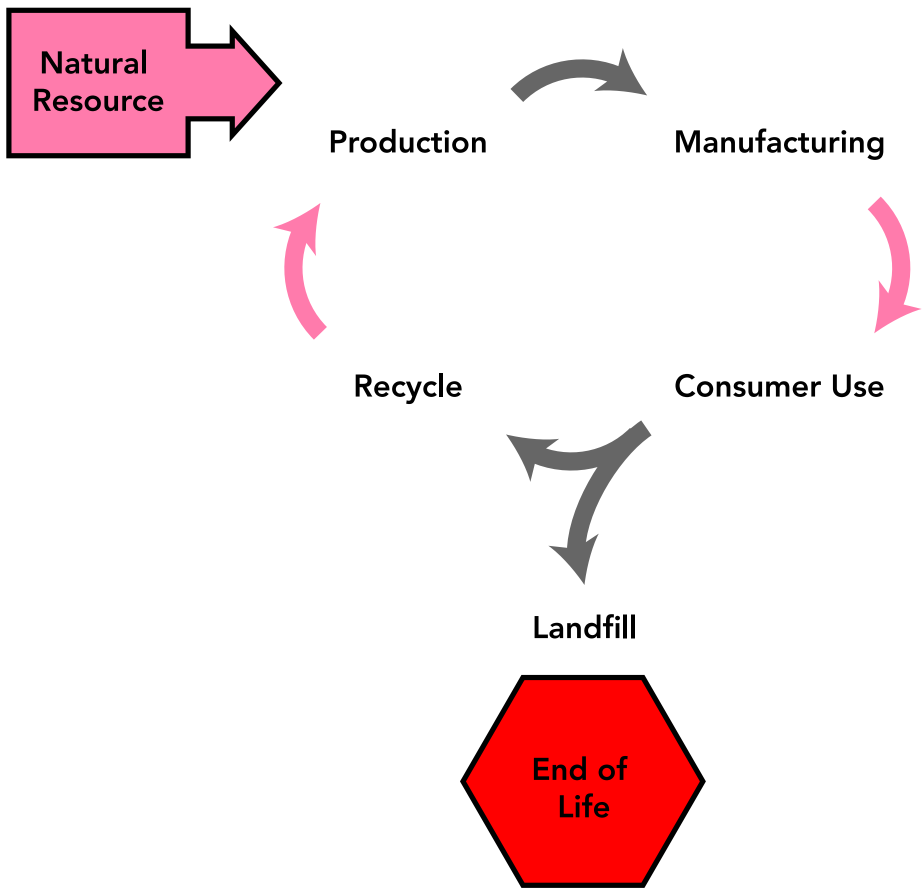
2025
McDonald's plans to source all packaging worldwide from sustainable sources.

Background Information for the Facilitator (Continued)

Even though plastics are invaluable for many purposes in modern life, the production and post-use of these items must also be taken into consideration. First, the raw materials for plastics (e.g., oil) must be extracted from their source, and this has associated financial costs and environmental impacts, such as leaving large **carbon footprints**. Secondly, the raw materials must be fashioned into a usable item, which also has a monetary cost and environmental impacts. Once plastic items have been used for their intended function, they have a varying post-use life. Some may be recycled, others may be reused, but many are simply discarded. Each of these post-use pathways has an environmental impact – positive and/or negative. Because most plastics have been developed with minimal thought for their ultimate disposal, there are increasing concerns that must be addressed with respect to the environmental consequences when these materials are discarded.

The data surrounding the environmental impacts of plastic show very high rates of carbon emissions as a result of plastic production. However, when looking at plastic alternatives, some research indicates that the carbon footprint of alternative products like glass or aluminum are also high. It is important to understand the **life cycles** (see diagram) of different products, to help make informed decisions as a consumer. Raw materials are first extracted from the Earth, then these materials are processed. After being processed, the products are manufactured and distributed to retail outlets to be purchased by consumers. After consumers use a product, they then make the choice to either **dispose** of, **recycle**, or **repurpose** the item. If they choose to dispose of an item, it ends up as solid waste in a **landfill**; if they choose to recycle, the item enters back into the life cycle at a different point and is reprocessed to make new items; and repurposing finds an alternative use for the item. **Note**: Not all plastic materials are recyclable. For those plastics that can be recycled, they may only be recycled one or two times, and are often downcycled into materials of lesser quality or value.

LIFE CYCLE OF MATERIALS DIAGRAM



The **Youth as Change Agents** part of this module is designed to engage youth in transforming plastic impact ideas into actionable projects. 3 5 Youth will work together to ask critical questions about our use of plastics based on their polymer science learning and discussions. Using an inquiry-based learning approach that best fits your program, youth will:

- Develop and implement an action project focused on a specific plastic issue.
- Gain knowledge, skills, and confidence to effectively serve as change agents around plastic related issues.
- Learn from other change agents, both youth and adults, who are working to solve the environmental challenges of plastics.

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Embrace struggle, overcome challenges, and increase self-confidence in STEM

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Polymer Science Inquiry

In this section of the module, youth will explore polymer science content through a guided inquiry activity. Each activity:

- Addresses issues in sustainability and the impacts of plastics.
- Engages youth in science and engineering practices.

If time and interest allow, facilitators can select additional polymer science exploration activities from the Polymer Science Exploration Grid located in the Front Matter Facilitation Tools.

Activity: Pitch Your Material

Youth prepare and deliver a marketing pitch to a fictional beverage company for a beverage container made from their assigned type of material (plastic, aluminum, or glass) using scientific information and a life cycle assessment. Youth will reflect as a large group on the advantages and disadvantages of each type of material.

Facilitator Opening Questions/Prompts (5-10 minutes)

Lead a conversation to anchor learning in youth's past experience with plastics.

- Discuss what you believe are the most common beverage containers people use and why that might be.
- Discuss your understanding of the materials used in packaging beverage containers for your favorite soft drink, juice, or water.
- Explain what type of materials – glass, aluminum, or plastic – you prefer when purchasing beverages. 1

Facilitator Tip
To enhance the activity, consider providing example containers made from aluminum, plastic, and glass.

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Connect STEM experiences to lives

PROCEDURE 1 (EXPERIENCING) (15-25 MINUTES)

1. Organize youth into small groups of two to four. 5 Assign each group one of the three materials: aluminum, glass, or plastic.
2. Provide each group with a blank life cycle chart (Appendix A-1) and a set of life cycle cards (Appendix A-2).
3. Provide each group with the graph of the historical trends relative to the use of aluminum, glass, and plastic (Appendix B). Ask the youth to review the graph.

Facilitator Tip
For those unfamiliar with a line graph, inform them that each point on the graph represents the total weight of a product that was manufactured in the year with which the point lines up on the horizontal axis. The data are presented in thousands of tons. For reference: 1 ton = 2000 pounds (for example: a small car, polar bear, or horse). 1,000 tons = 2,000,000 pounds (for example: small fishing boat, 148 elephants, 10 blue whales).

4. Ask groups to complete the life cycle chart using the information provided.
5. Invite groups to share their complete life cycle chart and explain their reasoning behind where they placed the life cycle cards.

PROCEDURE 2 (EXPERIENCING) (45-60 MINUTES)

6. Present the following scenario to the youth: each pair/small group is a manufacturing company that produces a beverage container using a specific material: glass, plastic, or aluminum. Based on the information they learn about the material they are assigned, each group will prepare and present a sales pitch to a new beverage company – TopFlite Nutri Water – as to why their material is best as a beverage container.
7. Hand out the information sheets on each type of material to each group (Appendix C 1, C-2, C-3). Be sure to provide all three sheets to every group so they have information on the other group's materials.

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Facilitator Tip
Encourage youth to use their completed material life cycle chart from Procedure 1.

8. Ask groups to: Develop a sales pitch (2-3 minutes in length) using the data from the graph (Appendix B) and the three information sheets (Appendix C). Describe your material's advantages and ways to overcome potential disadvantages of its use. Include a short description of evidence that supports each point. Sales pitches may include why your material is more advantageous than other materials in certain ways.

Science and Engineering
Point out to youth that they will be analyzing and interpreting data, communicating information, and engaging in an argument based on evidence, three of the practices scientists and engineers engage in.

Facilitator Tip
To help strengthen engagement, provide flip chart paper, markers, or other art materials and/or props for youth to use in their pitch. Invite them to be creative!

Encourage groups to propose solutions to make the current disadvantage of the product more advantageous. For example: (1) water bottles might make the cap smaller to reduce plastic use in their production; (2) a glass container might be designed to be converted to at-home glassware; or (3) only use recycled aluminum to manufacture new beverage containers and thus not needing to use newly mined aluminum.

Another idea might be for groups to describe an incentive on each bottle or can that includes a hashtag to use social media to document the consumer's recycling of the product.

9. Give groups 25 to 30 minutes to review the information sheets and prepare their sales pitch. Facilitator Tip: You may want to spend time with each group; if needed, offer ideas or answer questions youth may have.

10. Allow each group to present their sales pitch in front of the full group

11. If time permits, you may engage in a second iteration where groups have 5 minutes to prepare a counterargument to the other groups' claims about their material and offer another pitch.

Science and Engineering
In this activity youth are evaluating information, a science and engineering practice.

REFLECTION: SHARE, PROCESS, GENERALIZE (10-15 MINUTES)

Help guide youth as they question, share, and compare their observations. 2 You may choose one of the questions below as a prompt. If necessary, use more targeted questions as prompts to get to particular points. Remember these questions are not about getting one right answer. 3

- Describe what you learned about plastics, aluminum, or glass materials.
- Describe and compare the trends you observe in the production of glass, plastic, and aluminum.
- What do you predict the trends in material usage will look like in years: 10 years? 20 years? Why do you think this will happen?
- Explain what would influence your decision to purchase a specific type of beverage container made from plastic, aluminum, or glass.
- Describe what you think other alternatives there are to purchasing beverage containers in glass, plastic, or aluminum.

Science and Engineering
This discussion will help youth consider additional solutions, a science and engineering practice.

CONCEPT/TERM DISCOVERY

At this point, it is important to ensure that the terms **aluminum, carbon footprint, disposal, glass, landfill, life cycle, plastic, recycle, repurpose,** and **trend** have been discovered by or introduced to the youth. The goal is to have the youth discover terms and concepts on their own, defining and sharing them with their own words. If youth haven't already shown their knowledge of those concepts, revisit these ideas in a guided discussion.

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Youth as Change Agents

In this portion of the module, youth will turn their polymer science learning and plastic impact ideas into an actionable project. Youth will plan and implement an action project that reflects their questions related to plastics. Through this process, youth will gain knowledge, skills, and confidence to effectively serve as change agents around a plastic related issue. 2 3

Background Information for the Facilitator

Facilitators will guide youth through the process of developing an action project. Youth could choose a series of mini action projects or one in-depth action project. Outlined below are key learning and guiding questions for each step.

The action steps include:

1. Discovering the action project
2. Planning the action project
3. Putting the project into action
4. Sharing and reflecting on the action project

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WAYS TO APPROACH THE ACTION PROJECT

The approach you choose will vary depending on the plastic issue youth want to address. For example, youth may want to study microplastics in the local waterway and collect data to contribute to a scientific study to help inform the public. This action project could use a citizen science approach **or** geo-inquiry approach, depending on the goals of your group. Youth may want to:

- Conduct a scientific investigation including data collection and analysis.
- Embark on an action project to improve a condition in their school or community.
- Start an advocacy campaign to change a condition or policy.

The Change Agent Approach Matrix included in the Front Matter is a guide to help determine the best approach to address the group's question or chosen plastic issue. Here is a brief description of each approach:

- **Citizen science** – an approach where youth collect data which is shared with the professional scientific community to study real-world phenomena.
- **Geo-inquiry** - an approach where youth analyze space, place, and human conditions through maps usually with the aid of geographic information systems (GIS).
- **Community engagement** – an approach where youth get involved in an organized effort on behalf of another government or nonprofit organization to benefit the community.
- **Service learning** – an approach where youth develop a project to benefit others and their community. Service learning can be a direct-service, indirect service, or advocacy-based service project that does not include data collection.
- **Youth participatory action research (YPAR)** – an approach where youth define an issue and research question, conduct an investigation (data collection, analysis), and then take action based on the results. In YPAR, youth develop a project where they collect and analyze data, followed by a service-learning project informed by their data outcomes.

PROCEDURE

Facilitate a group discussion to help youth ask critical questions about our use of plastics. You may choose one or more of the questions below to help guide youth in connecting concept understanding to taking action. Record youth's observations, questions, and discussion on flip chart paper. This discussion will help ground youth in the larger issues as they move into discovering their action project.

- What do we care about regarding our world's use of plastics and their impact? 1
- Describe your reasons for why people should continue or change their behavior around their use of aluminum, glass, and plastic

Science and Engineering
Youth engage in defending your viewpoint by stating evidence or reasons, a science and engineering practice.

- Imagine a perfect future. What does plastic use and disposal look like?

Lead youth through the key core learning experiences for steps 1-4 using the guiding questions.

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Step 1

DISCOVERING THE ACTION PROJECT

Youth generate, discuss, advocate, and select a handful of issues or questions to explore.

The goal is to have students contribute to something larger than themselves and achieve broader impact.

Science and Engineering

Youth engage in asking questions and/or defining problems, a science and engineering practice.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Discovering the Action Project • Youth ask questions and discuss issues related to plastics. • Youth brainstorm/generate ideas for a project/plan to address the issue. • Youth record ideas. • Youth identify what additional information is needed to select a project/plan. • Youth determine ways to address/ solve the issue. 2 • Youth will identify how the project will make a positive change. • Youth select a project.	**Discovering the Action Project** • What do we already know about plastics in our community/world? • What do we wonder about plastic use and the environment? • What information do we need to know about plastics in our community or world (research)? • What critical issue related to plastic use and its environmental impacts do we want to address? • What action can we take to answer or address the question or issue? • How does what we learned about polymers influence how we want to take action?

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Facilitator Tip
Highlight scientists and change agents who are currently working to address real life plastic issues using different approaches. Facilitators can showcase a video from the NSF Center for Sustainable Polymers (https://csp.umn.edu/) or read about innovators transforming the way we use plastics and the way plastics are made. 6 See the Change Agent Approach Matrix including in the Front Matter for examples.

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Interact and learn from diverse STEM role models

Step 2

PLANNING THE ACTION PROJECT

Youth plan and prepare the various steps of the action project in order to be successful.

The goal is for youth to gain project planning skills of organizing tasks, determining resources needed, and creating a project timeline.

Science and Engineering

Scientists and engineers also use this practice of planning their investigation.

CORE LEARNING EXPERIENCES

Planning the Action Project

- Youth discuss and determine project goals.
- Youth identify resources.
- Youth create action steps/data collection plan to guide the project.
- Youth determine who will do what by when.

GUIDING QUESTIONS

Planning the Action Project

- What do we want to achieve in this project?
- What skills do we need to accomplish this project? How could we gain them? Who can help?
- Who can we invite to partner with us on planning the project? (elected officials/government representatives, businesses, schools or non-profits)? 5
- What steps do we need to take to achieve this goal?
- What resources do we need to help us achieve our goal?
- What is our timeline - which activities will we do by when?
- What are the roles for our group members (who will do what when)? 5
- What else do we need to know to help us be more prepared for this project?

Facilitator Tip
Change Agent Project Planning Tool can be used when developing a detailed project plan (see Front Matter).

Facilitator Tip
During the planning the action project process, youth should identify a range of people in the community that can support their action project. Before reaching out to community members, guide youth as they craft written correspondence, social media posts, and in-person interactions with community members. This will help youth develop and grow their communication skills and gain confidence. Please see the Front Matter for additional resources to support youth in developing their communication skills.

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Step 3

PUTTING THE PLAN INTO ACTION

Youth engage in final project preparation steps and then experience carrying out their action plan.

The goal is for youth to gain confidence through project implementation to effectively serve as change agents and engaged citizens around issues of plastics.

Science and Engineering

Carrying out their planned investigation is a science and engineering practice. 3

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Putting the Plan into Action • Youth implement an action plan. • Youth share project impact/project research. • Youth determine project sustainability.	**Putting the Plan into Action** • What final preparation steps do we need to take in order to implement the plan? • Are there additional people we can invite as we put the plan into action - peers, family members, community members, leaders, others? 5 • How will we record what we did? • How will we share the results of our work? Is it already part of the project (for example, in a citizen science project protocol)?

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Facilitator Tip
Governmental departments, elected officials, and businesses may be eager to support your action project, especially if it aligns well with their mission and goals. They may offer hands-on support of the project (setting up a tour of the local recycling center or a recycling business).

Facilitator Tip
Be sure to take pictures or video during the action project or designate a youth or adult to be the photographer.

Step 4

SHARING AND REFLECTING ON THE ACTION PROJECT

Youth reflect on the action project and share results (e.g., presentations; videos; newsletter/newspaper articles) with peers, community leaders, members of their communities, and other venues.

The goal is for youth to evaluate the project impacts, both on the community and on their own experience.

Science and Engineering

Several science and engineering practices occur in this step, including analyzing and interpreting data, constructing explanations or designing solutions, engaging in argument based on evidence, and communicating information.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Sharing and Reflecting on the Action Project • Youth analyze and evaluate the project's impact. • Youth reflect on personal learning. • Youth publicly showcase the project. • Youth share results with community and stakeholders. • Youth celebrate project impact and personal contributions.	**Sharing and Reflecting on the Action Project Youth Learning:** • Why did we choose this project? • What was our main goal? What did we accomplish? • What ways did we impact the plastic issue in our community/world? • What could the future of this action/ project look like? • Are there new questions or ideas? • If we were to do this project again, what would we do differently? • Who else can we share our actions/ finding with? • How might we or the community continue elements of the project? • What do you think would happen if more people did this same project?

	GUIDING QUESTIONS (CONTINUED)
	Youth Leading: • What did we learn? • What skills did we gain? • What was our favorite part of the project? • What was the hardest part of the project? 3 • How do we feel about what we accomplished in the project? • How do we feel about how our group worked together during the project? • What leadership skills did we gain through the project? • What communication skills did we gain as a result of our project? **Celebrating:** • Who helped us along the way? How should we thank them? 5 • Who else can help elevate and share our actions and findings? How can they help us continue our efforts? • How can we all celebrate together?

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Facilitator Tip
Use the Change Agent Action Project Evaluation sheet (see Front Matter) to evaluate the outcomes and impact of the action project as well as reflect on personal skills gained through the process. Personal reflection can also include writing, pictures, charts, or other expressions that assess the impact of the project. Create an opportunity for group reflection.

Facilitator Tip
Celebrating provides an opportunity to publicly recognize positive achievements and personal growth of youth. Depending on time available, offer a public showcase of what youth learned and accomplished during the action project. If time is limited, provide certificates of recognition.

CONGRATULATIONS CHANGE AGENTS!

Through the Youth as Change Agents experience, youth addressed the complex issues of plastics in our communities, our country, and our world. Youth gained valuable leadership skills by planning and implementing a plastic focused action project reflective of their interests and passions. They successfully served as important change agents and engaged community members to imagine a new future of plastics. Please be sure to share your action project via #4HSolvetheChallengeofPlastics.

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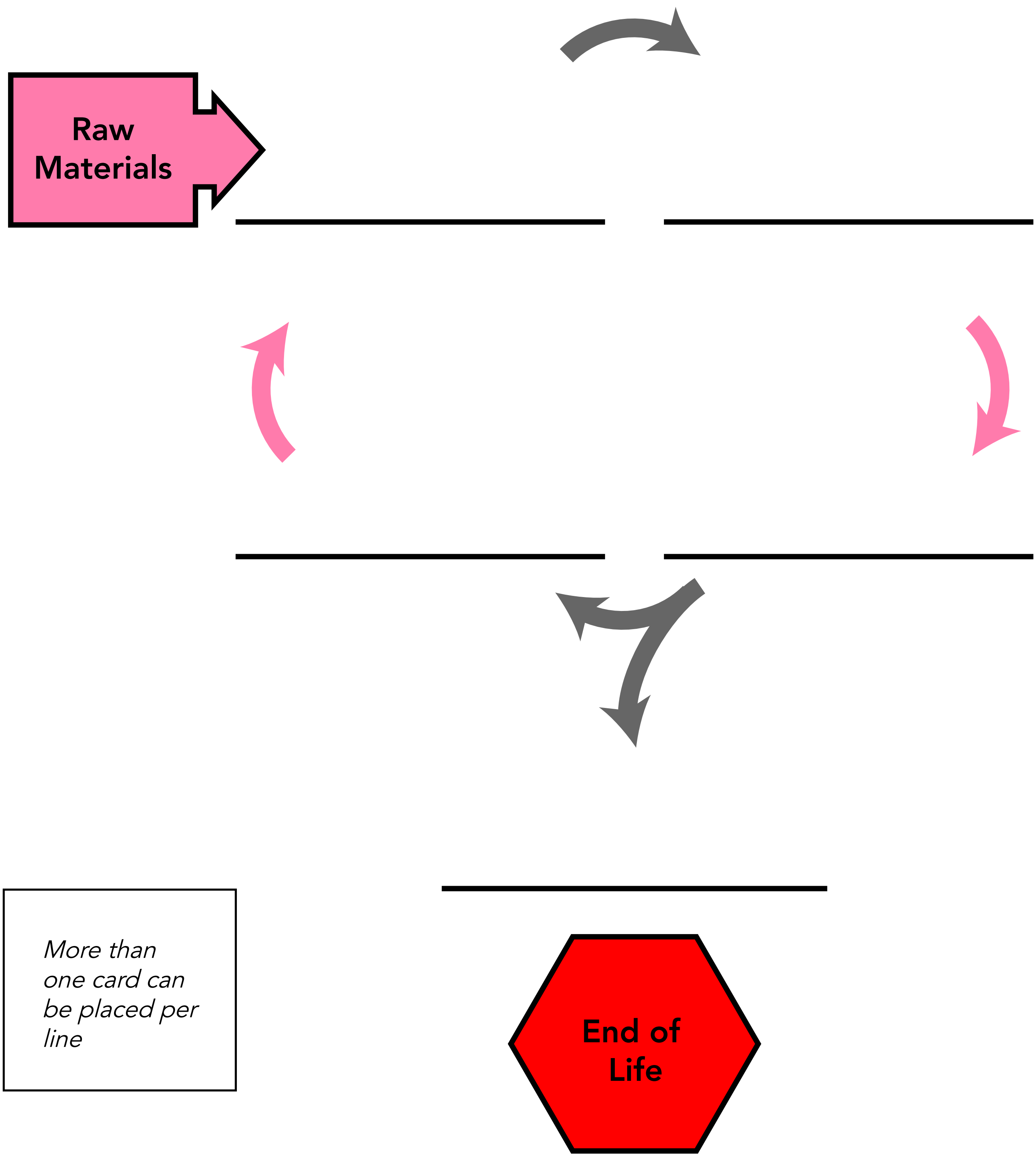
Appendix A-1
Blank Life Cycle

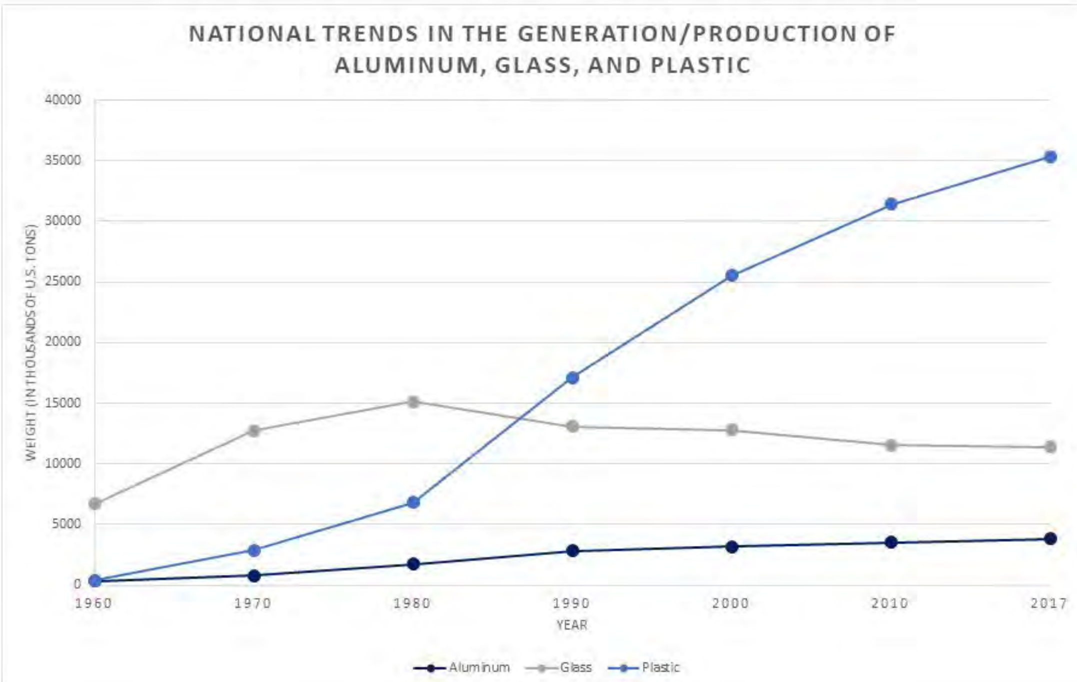


Appendix A-2

Extraction Raw materials are withdrawn from the Earth	**Manufacturing** Process of making products with raw materials using power and machinery
Transportation Product is transported to stores, restaurants, and warehouses	**Consumer Use** People purchase product and use it
Disposal the action of throwing away or getting rid of something	**Landfill** site where trash is taken
Recycle process of converting waste materials into new objects	**Repurpose** adapting for use in a different purpose

Appendix B

National Trends in Aluminum, Glass, and Plastic Generation/Production

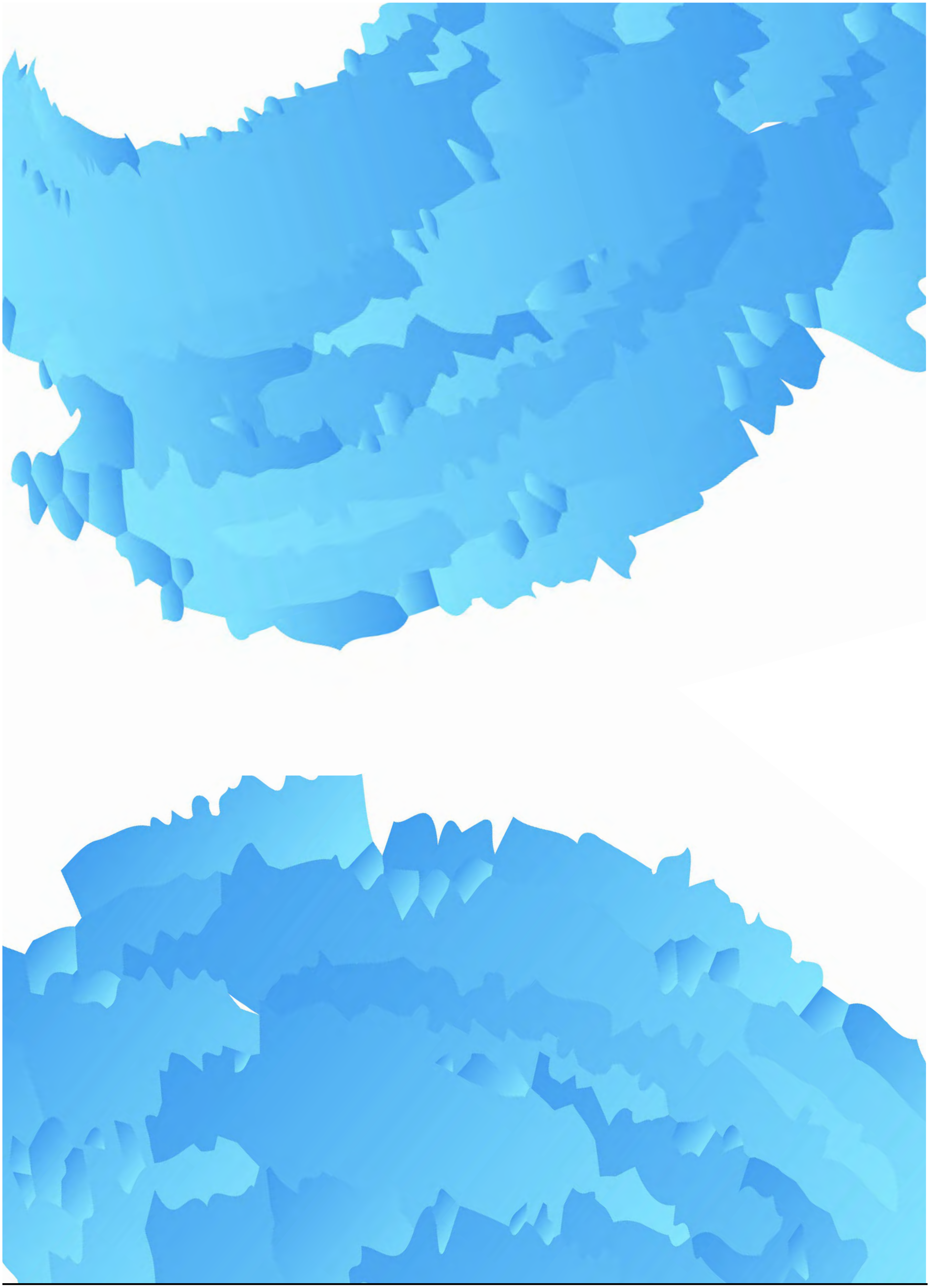


The data are presented in thousands of tons. For reference:

- 1 ton = 2000 pounds (for example: a small car, polar bear, or horse)
- 1,000 tons = 2,000,000 pounds (for example: small fishing boat, 148 elephants, or 10 blue whales).
- On the graph, 20,000 tons would weigh as much as 200 blue whales.

Glass: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/glass-material-specific-data
Aluminum: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/aluminum-material-specific-data
Plastic: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data

Data are presented by weight in thousands of tons.
Data accessed from: Environmental Protection Agency Material-Specific Data for Glass, Aluminum and Plastic (www.epa.org)



Appendix C

Material Information Sheets for Aluminum

Prepare and present a sales pitch to a new beverage company – TopFlite Nutri Water – as to why aluminum is best for them to use as a beverage container.

Describe aluminum's advantages and ways to overcome potential disadvantages of its use. Include a short description of evidence that supports each point. Sales pitch may include why aluminum is more advantageous to plastic and glass in certain ways.

ALUMINUM

A light silvery-gray metal commonly used for beverage containers and foil wrap.

Extraction

- Aluminum is found in a clay-like rock. It is mined in tropical and subtropical areas of the world.
- The mining process often involves cutting down entire forests.
- The energy used to create aluminum causes air pollution (greenhouse gas emissions) and water pollution (in streams, ponds and lakes, and groundwater).
- Aluminum is considered a non-renewable resource because it is available in limited quantities.

Manufacturing

- Metal is transported to the processing plant. Transportation releases greenhouse gasses.
- Fossil fuels are burned for energy during manufacturing, resulting in air pollution.
- The scrap aluminum can be used to make cans for beverages.
- The use of the excess aluminum and recycled aluminum cans can reduce the use of fossil fuels, making it more environmentally friendly.

Consumer Use

- Aluminum cans are lightweight and durable.
- Once the aluminum beverage containers have been produced and filled with your favorite soft drink or water, the cans are brought to your local supermarket or vending machine.

Disposal

The choice we make on how we dispose of an aluminum can determines its fate.

- **Trash**: Cans are brought to landfills when they are discarded in the garbage bin. Although some materials, such as food scraps, decay in the soil quite readily, aluminum cans may take more than 100 years to decompose. Additionally, there are other problems associated with landfills, including surface water pollution (e.g., streams, lakes, and ponds), groundwater pollution, and production of the greenhouse gas methane.
- **Recycle**: Recycling aluminum means they can be made into new cans. This is great because aluminum can be recycled indefinitely. US recycles on average 16% of aluminum.
- **Repurpose**: Repurposing aluminum cans involves thinking of other ways to use them. For example, the tops of aluminum cans can be removed and then used as storage containers in a workshop to hold nails or screws. By repurposing an aluminum can, it is not only being recycled, but also reducing waste in the landfills.

Appendix C-2
Material Information Sheets for Glass

Prepare and present a sales pitch to a new beverage company – TopFlite Nutri Water – as to why glass is best for them to use as a beverage container.

Describe glass's advantages and ways to overcome potential disadvantages of its use. Include a short description of evidence that supports each point. Sales pitch may include why glass is more advantageous to plastic and aluminum in certain ways.

GLASS

A hard brittle and transparent substance made from sand commonly used to make windows and containers.

Extraction

- The most commonly used glass is made from the raw materials sand, limestone, and soda ash.
- Large amounts of greenhouse gasses are emitted into the atmosphere during extraction.
- After the raw materials are processed, they are transported to a manufacturing facility. Transportation releases greenhouse gasses.

Manufacturing

Once raw materials reach the manufacturing facility, they go through a four-step process and each stage requires fossil fuels which releases greenhouse gasses. Fossil fuels are burned for energy during manufacturing, resulting in air pollution.

1. The sand, limestone, and soda ash are mixed together.
2. The mixture goes through a furnace to be melted and refined. At this stage, the highest amount of greenhouse gases is released into the atmosphere.
3. The glass is then shaped and formed. Forming helps to shape the glass.
4. Finally, the glass goes through a final forming process to make the final product.

Disposal

The choice we make on how we dispose of a glass bottle determines its fate.

- **Trash**: Glass is brought to landfills when they are discarded in the garbage bin. Landfills are disposal areas where solid waste is buried and covered with a layer or two of soil. Since glass is such a sturdy material, it can take millions of years to decompose in a landfill. Additionally, there are other problems associated with landfills, including surface water pollution (e.g., streams, lakes, and ponds), groundwater pollution, and production of the greenhouse gas methane.
- **Recycle**: Glass bottles are 100% recyclable. Recycling glass bottles helps conserve energy when compared to the first manufacturing process of the raw materials. Recycled glass also has a lower melting point, therefore, reducing the energy needed to melt the glass during the manufacturing process. US recycles on average 27% of glass.
- **Repurpose**: Choosing to repurpose glass involves thinking of new ways to use the product. Glass bottles are commonly used as flower vases and for other decorations.

Appendix C-3

Material Information Sheets for Plastic

Prepare and present a sales pitch to a new beverage company – TopFlite Nutri Water – as to why plastic is best for them to use as a beverage container.

Describe plastic's advantages and ways to overcome potential disadvantages of its use. Include a short description of evidence that supports each point. Sales pitch may include why plastic is more advantageous to glass and aluminum in certain ways.

PLASTIC

A type of material that can be molded into solid objects and is usually made from petroleum/oil.

Extraction

- Plastic is composed of polymers, or large molecules made of smaller monomers, and historically made from oil (including petroleum and natural gas). Some are now made from renewable materials (such as corn, potatoes, or cotton).
- Petroleum is removed from underground and refined into a variety of materials. There can be negative side effects for animals, humans, and the environment from extracting oil.
- Oil is considered a non-renewable resource because it is available in limited quantities and takes a long time to be replenished (i.e. millions of years).

Manufacturing

- Oil is transported to the manufacturing plant. Fossil fuels are burned for energy during manufacturing, resulting in air pollution
- Manufacturing involves creating the plastic resin and then making it into bottles.
- Empty bottles must then be transported to the processing plant to be filled with the liquid beverage. Plastic weighs less than glass, so transportation emits less greenhouse gasses.

Consumer Use

- Plastic beverage containers are lightweight and durable.
- Once the plastic beverage containers have been produced and filled with your favorite soft drink or water, the bottles are transported to your local supermarket or vending machine.

Disposal

The choice we make on how we dispose of an aluminum can determines its fate.

- **Trash**: Plastics are brought to landfills when they are discarded in the garbage bin. Plastic materials can take hundreds to thousands of years to decompose because most are not able to break down and decompose. Additionally, there are other problems associated with landfills, including surface water pollution (e.g., streams, lakes, and ponds), groundwater pollution, and production of the greenhouse gas methane.
- **Recycle**: US recycles on average 8% of all plastic; however, around 30% of plastic bottles are recycled. Recycled plastics are sorted at a recycling plant, then sent to a reprocessing plant where they are made into new materials. Plastics are made from different types of polymers and must be processed differently. While some containers are made from a single type of plastic, others are made of multiple plastic types and are much more challenging to recycle.
- **Repurpose**: Plastic bottles may sometimes be used for other purposes.

Send us your Feedback!

Have you tried one (or more!) of the activities? Let us know how it went! We work with the Center for Applied Research and Education Improvement at the University of Minnesota to evaluate this project. Click on the button below to fill out their short evaluation form and help us collect valuable feedback for improvement!

4hpolymers.org/evaluation