Make Mushroom Packaging to Explore Long-Term Ecological Impact

Student worksheet — *Answer key*

VOCABULARY: Use the words below as you fill in this worksheet.

CO_2 Equivalent: The number of kilograms of CO_2 emission that creates the same global warming potential as 1 kg of another greenhouse gas.

Life cycle assessment (LCA): A systematic study that looks at the environmental impacts of a product or service throughout the entire *product life cycle*.

Mycelium: The root structure of mushrooms.

Mycelium composite: A material created by growing mycelium around organic material like wood chips.

Product life cycle: The stages a product or service goes through, from its raw materials to its disposal (sometimes called cradle to grave).

I Introduction

DIRECTIONS: Answer the questions below.

1. What do you think is the ideal end of life for a product? Where should it ideally end up?

2. On a scale of 0 – 5, 0 being the ideal end of life, how ideal would you rate the end of life of the bags listed in Table 1? (Write your ratings in Table 1.)

3. On a scale of 0 – 5, 0 being no environmental impact and 5 being extremely taxing to the environment, how would you rate the bags listed in Table 1? (Write your ratings in Table 1.)

Make Mushroom Packaging— Page 2

Table 1: Perceived Ecological Impact of Shopping Bags		
Material	**End of life rated on a scale of 0 - 5**	**Environmental impact rated on a scale of 0 - 5**
Single-use plastic bags		
Single-use biodegradable plastic bags		
Brown paper bags		
Cotton bags		
Thick, reusable plastic bags		

4. Which statement do you think is correct?
   - ☐ An end-of-life rating is identical to an environmental impact rating.
   - ☐ An end-of-life rating is the most important component of an environmental impact rating.
   - ☐ An end-of-life rating is only one out of many factors that make up an environmental impact rating.
   - ☐ An end-of-life rating is not related to an environmental impact rating.

DIRECTIONS: Watch the video, linked below, and use the information given in the video to complete questions 5-9.

- Video: https://youtu.be/JvzvM9tf5s0

5. What fact(s) discussed in the video surprised you?

6. Define "*life cycle assessment*" in your own words.

   The definition is given in the word-bank. Students should include the following:

   - *Looks at environmental impacts*
   - *Includes every step along the life cycle*
   - *Tries to quantify each impact*

7. What impacts on the environment were included in the study shown in the video?

   The study compared:

   - *Climate change potential, or greenhouse gas emission – expressed in kg CO_2-e.*
   - *Total environmental impact, which includes 15 effects on the environment (toxicity, ozone depletion, resource use, water use, runoff, etc.)*

8. According to the video, what important factor cannot be captured in a number, and thus, is not included in the life cycle assessment?

   - *Litter is not included.*

9. List some reasons why one would make a *life cycle assessment.*

   Some examples are:

   - *Allows a comprehensive way to look at the environmental impact of a product.*
   - *Creates data so decisions on changes aimed to make the product eco-friendlier are grounded in data.*
   - *Explore quantitatively the environmental impact of changes in a products' life cycle, for example, to quantify the impact of a switch in raw materials.*
   - *To do a cost-benefit analysis: what change in the life cycle will have the largest reduction in environmental impact?*
   - *Allows companies to communicate their environmental impact and the measures they take to mitigate them in a credible way.*

DIRECTIONS: Watch the video below until timestamp 02:47 and use the information given to complete steps 10-12.

- Video: https://www.youtube.com/watch?v=uznXI8wrdag

The video talks about *mycelium composite*, a material created by growing mycelium around agricultural waste, and how it can be used as packaging material.

10. List some aspects related to the environmental impact of this material that are addressed in the video.

    - *End-of-life: compostable*
    - *Raw materials: agricultural waste, water, mycelium*
    - *Transportation: This product is slightly heavier. (This will lead to a larger impact of transport compared to a lighter packaging material.)*

11. List some aspects related to the environmental impact of this material that are not addressed in the video.

    Below a few examples students might list:

    - *Does the agricultural waste need preprocessing?*
    - *How much energy is needed to grow mycelium?*
    - *How much more will the environmental impact of transportation be?*
    - *How well does it protect the goods?*

12. List some questions you asked yourself after watching this video.

II Grow a Mycelium Composite Packaging Product

DIRECTIONS: Complete step 13-19.

13. What is the packaging product you will make and study (e.g., small planters, boxes to transport fruit and vegetables, etc.)?

    An example could be planters for seedlings.

14. What material is it typically made of?

    An example is high-density polyethylene.

15. List the raw materials needed to grow this mycelium composite product. Include quantities where possible.

    An example is given below. Your students might have different answers as they might use a different kit!

    Products in the kit: *Hemp (0.9 lbs.), mycelium*

    Added during activation of the kit: *Water (3 cups), flour (4 tbsp)*

    Added during the growth: *Flour (4 tbsp)*

    Miscellaneous products used in the process: *70% isopropyl alcohol (a few ml), vinyl gloves (3 pair), plastic bag, clips (reusable), baking pan (reusable)*

    Energy used in the process: *Baked the product at 200°F for 20 minutes.*

16. Mass of the final product: *50g*

17. Approximately what fraction of the kit was used to make your product?

    One way of approximating this is by weighing all the products made from 1 kit and divide the mass of each product by the total mass.

    E.g., My product weighed 100g, and the total of all products made from this kit weighed 500g, thus my product used 100g/500g or 1/5 of all the materials listed.

18. Evaluate the quality of your product.

    List the data you collect and your findings on a separate piece of paper.

    Here are some aspects to consider:

    - How well is it able to fulfill its job as packaging material? Is it strong enough, shock-absorbent enough, will it break down when wet, etc.?
    - How does it compare to the typical packaging material that you are studying (the material listed in question 14)?

19. Which, if any, aspects of your product would need to change to be a viable alternative compared to the typical packaging material you are studying?

III Product Life Cycles

DIRECTIONS: Complete steps 20 – 22.

20. What is the packaging product you are making?

    An example is planters for seedlings.

21. Look up information on the *product life cycle* of the product you listed in questions 13 and 14, or a typical alternative for the product you are making, especially information that might help assess its environmental impact. Research the following steps of the life cycle:

    - Raw materials
    - Manufacturing
    - Transportation
    - Disposal

    You will annotate the provided life cycle template shown on pages 9 and 10 with anything that flows into or out of these steps in the life cycle. Examples are raw materials, renewable energy, non-renewable energy, water, waste, air pollutants, etc. Add numerical data, if available.

    For numerical data:

    Choose the base unit (e.g., 1 ton of finished product, 1000 planter pots, etc.) This unit is arbitrarily chosen and serves as a base to express all inputs and outputs in terms of this unit.

    Express everything that flows in or out at each step in terms of this unit (e.g., if 2.1 kg of water is used to create 1 kg of polystyrene, 2.1 tons of water is used to create 1 ton, or 1 base unit of finished product. Annotate the production step with 2.1 tons of water flowing in.)

    Keep a list of references, especially for quoted numerical data.

    Add a question mark next to information that is plausible, but of which you are unsure.

Figure 1 is an example of an annotated life cycle of polystyrene packaging material. Go over this example with your group or with the class and make sure you understand what to do before you start your own.

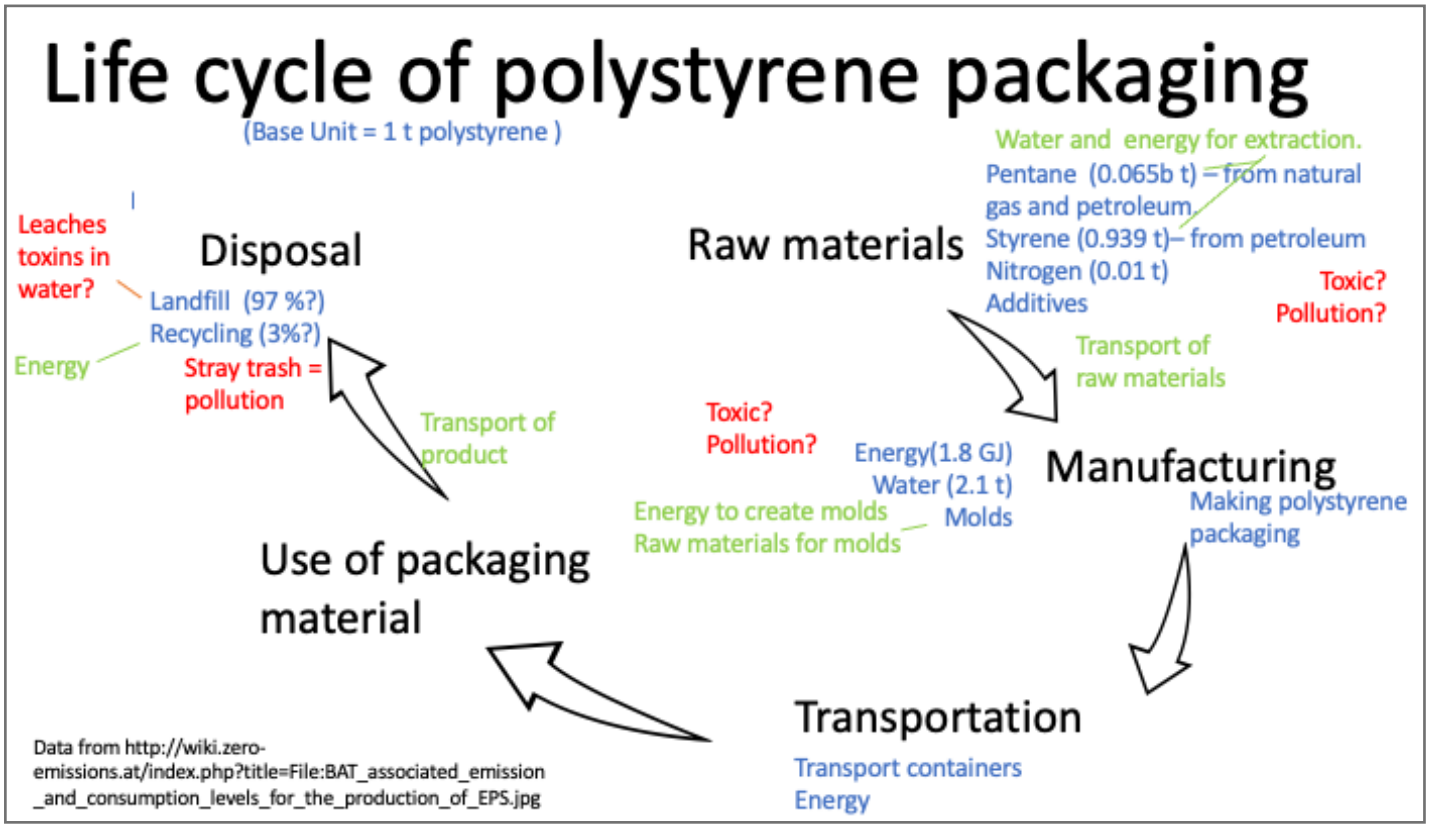
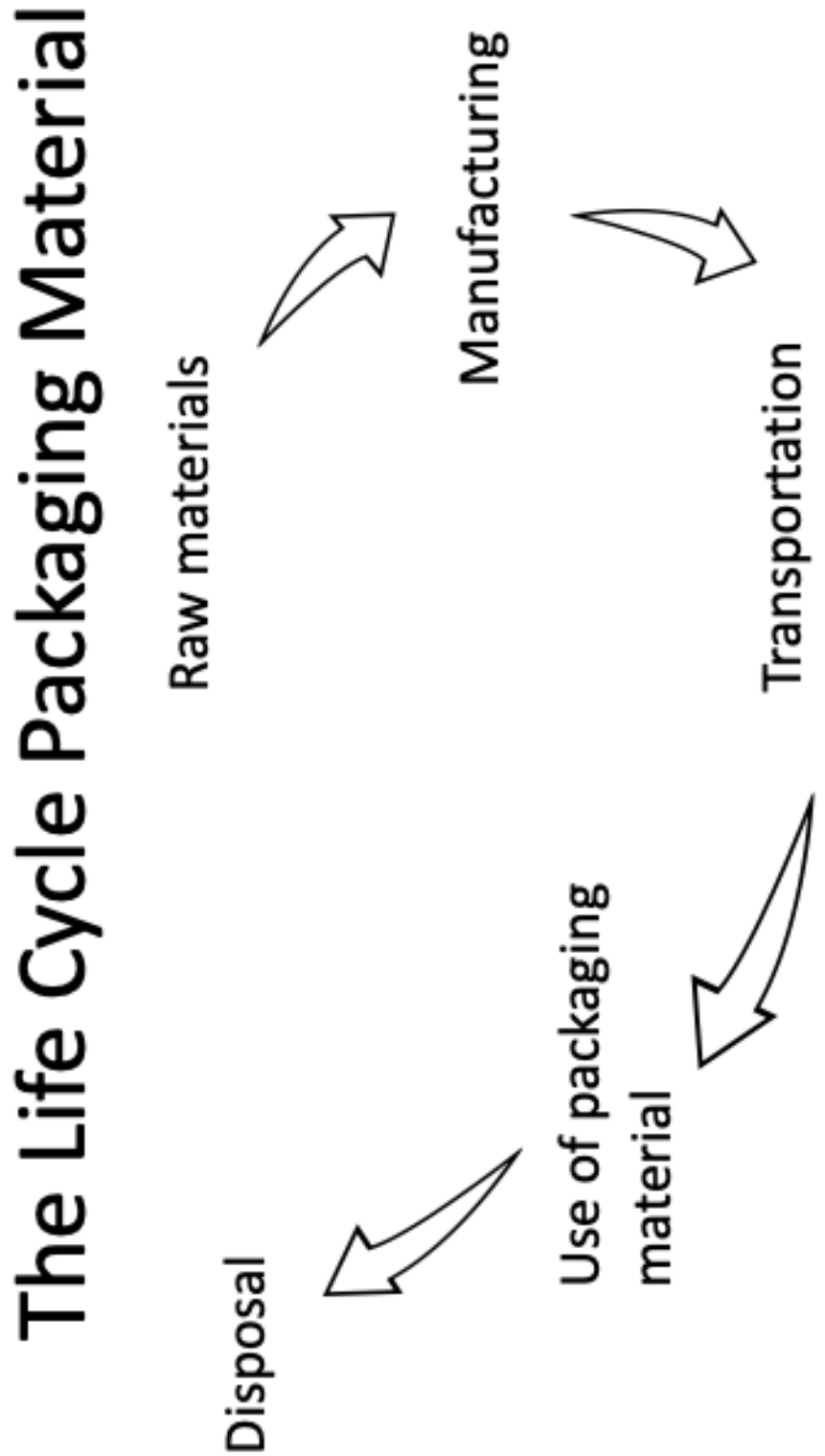
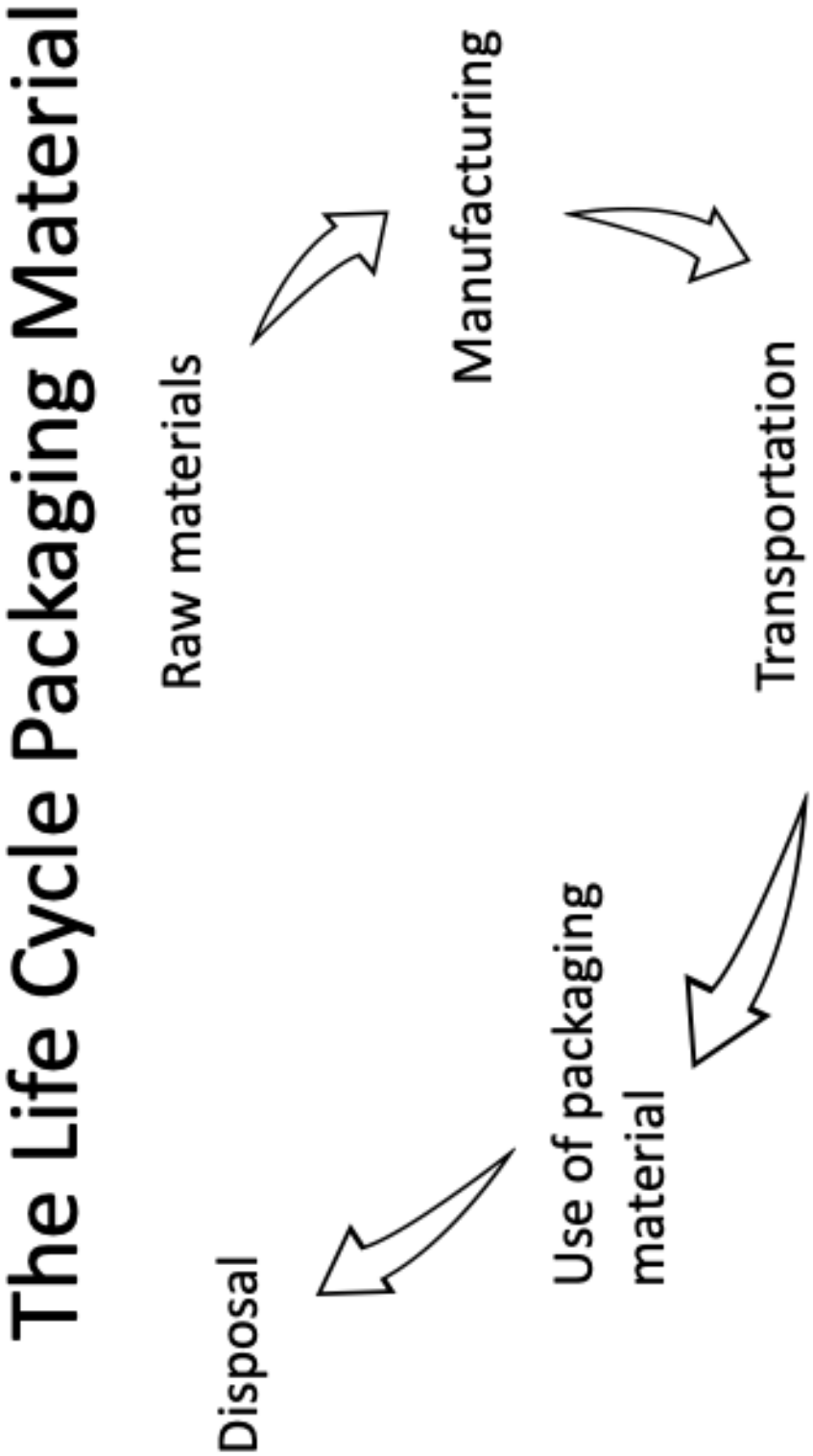


Figure 1

22. Repeat step 21 to annotate a life cycle for industrially created mycelium composite packaging material. Use your experience from growing mycelium composite packaging material, in addition to information you find online.


The Life Cycle Packaging Material
Raw materials
Manufacturing
Transportation
Use of packaging material
Disposal


The Life Cycle Packaging Material
Raw materials
Manufacturing
Transportation
Use of packaging material
Disposal

IV Life Cycle Assessments

DIRECTIONS: Complete steps 23 – 24.

A life cycle assessment evaluates the product on several aspects. Some common aspects included in a life cycle assessment are:

Global warming potential (expressed in CO_2-equivalent in kg) – the heat being absorbed by any greenhouse gas in the atmosphere.

Ecotoxicity potential (expressed in 1,4-dichlorobenzene-equivalent in kg) – the potential of biological, chemical, or physical toxic effects on ecosystems.

Human toxicity potential (expressed in 1,4-dichlorobenzene-equivalent in kg) – the potential at which substances can harm humans or animals.

Acidification potential of land and water (expressed in SO_2-equivalent in kg) – the potential certain chemicals have to acidify land and water.

Eutrophication potential (expressed in $(PO_4)^{3-}$-equivalent in kg) – the potential of over-fertilization and excessive supply of nutrients to impact land and water.

Non-renewable energy (or fossil fuel) indicator – indicator of the use of non-renewable energy, mainly acquired by the burning of fossil fuels.

Depletion potential for non-fossil resources (expressed in Sb-equivalent in kg) – indicator of use of non-renewable resources other than fossil fuels, e.g., clay, minerals, etc.

Ozone depletion potential (expressed in CFC-11-equivalent in kg) – potential to degrade the ozone layer.

Freshwater depletion – potential to deplete freshwater water reservoirs.

Solid waste – potential to create solid waste

23. Choose two aspects from the list above to study. Each of them should impact at least one of your life cycles.

    Chosen aspect 1:

    Chosen aspect 2:

24. Go through the following steps for each chosen aspect:
    - Look up the aspect you are studying and what the unit it is defined in means.
    - Indicate the instances in the life cycles that contribute to the chosen aspect. For example, extracting raw materials and production contribute to the total freshwater use for the polystyrene life cycle.
    - Look up quantitative data on each of these instances. For example, find quantitative data on how much fresh water is used to extract the raw materials to produce 1 ton of polystyrene. This step will take some effort, and you might need to make assumptions, or do some calculations. Keep track of these and of the references used. Here are some guidelines to find data where no exact numbers are available:
        - Consider using an average.
        - Consider making educated guesses where needed, for example on the transportation method used, and distance traveled. Use these educated guesses to calculate a reasonable estimate; for example, for the carbon emission due to transportation.
    - Write the result; for example, 9,022 L water, next to the instance on the life cycle overview. Use the templates shown on pages 14 and 15 to collect the assessment information, one template per product.
    - Once you have evaluated all instances for this aspect on both life cycles, compare the different instances. Visualize the numbers (approximations are fine) so the large contributors are instantly identifiable.

Figure 2 is an example of an annotated life cycle of polystyrene packaging material, in which water use and global warming potential are evaluated.

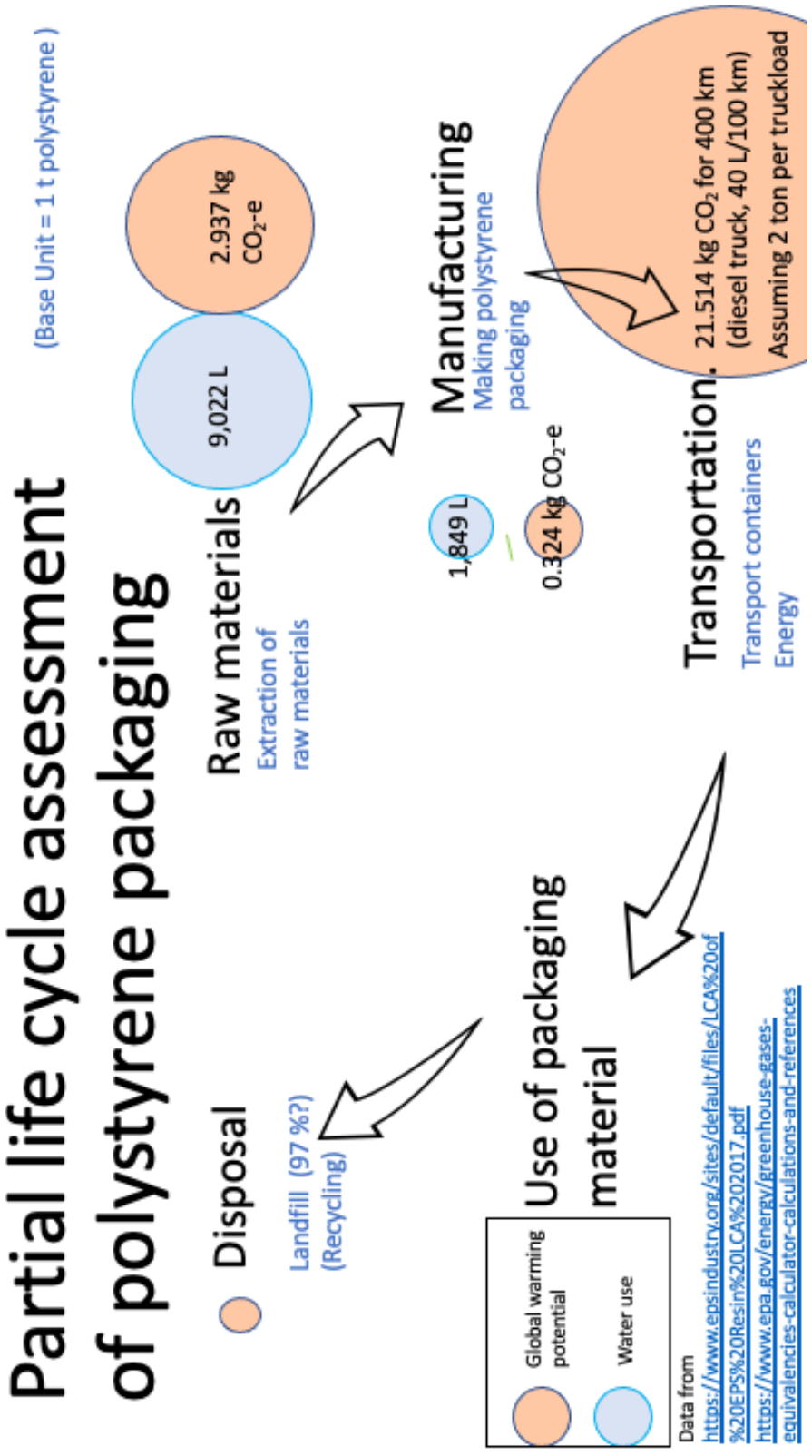
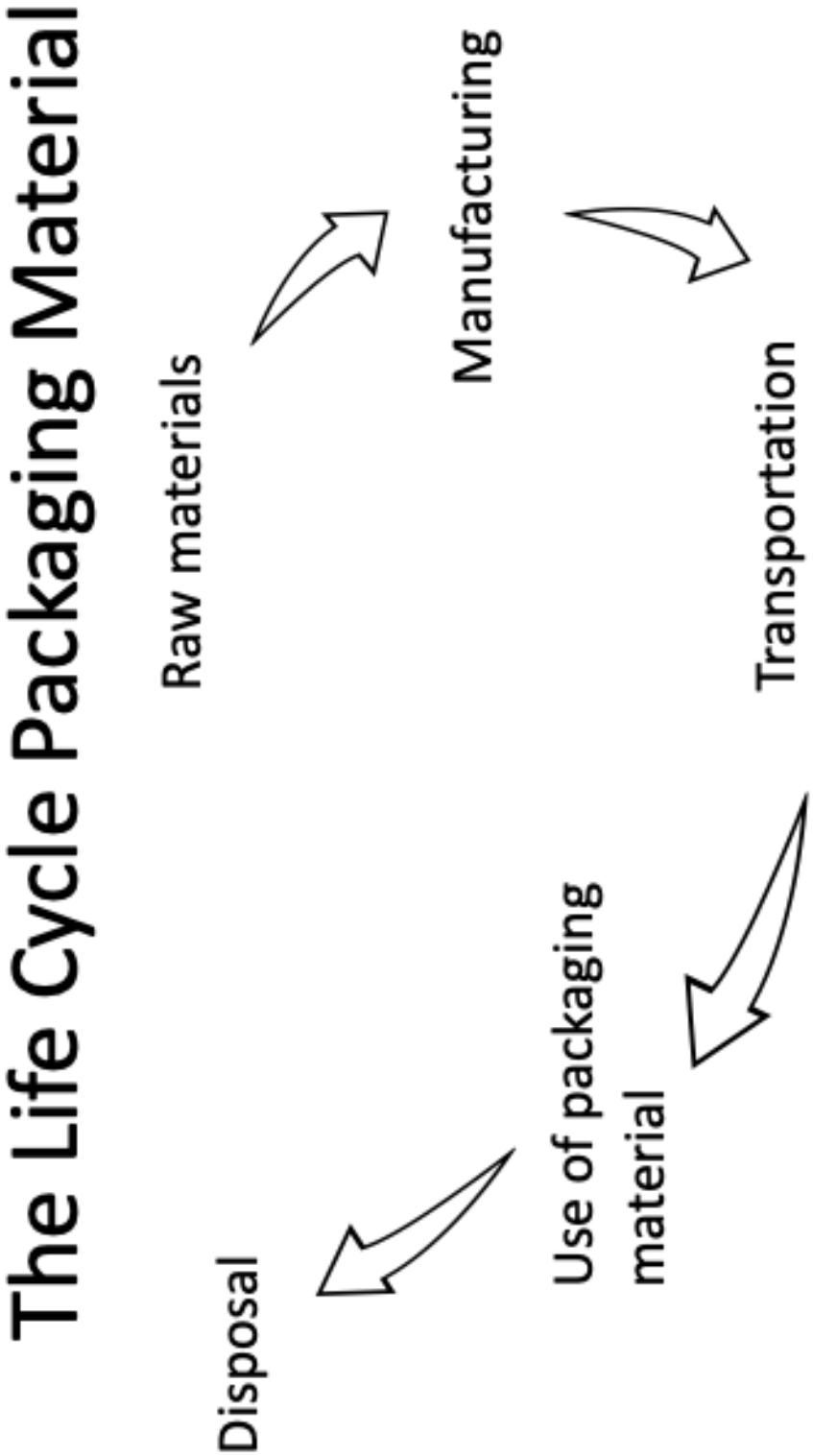
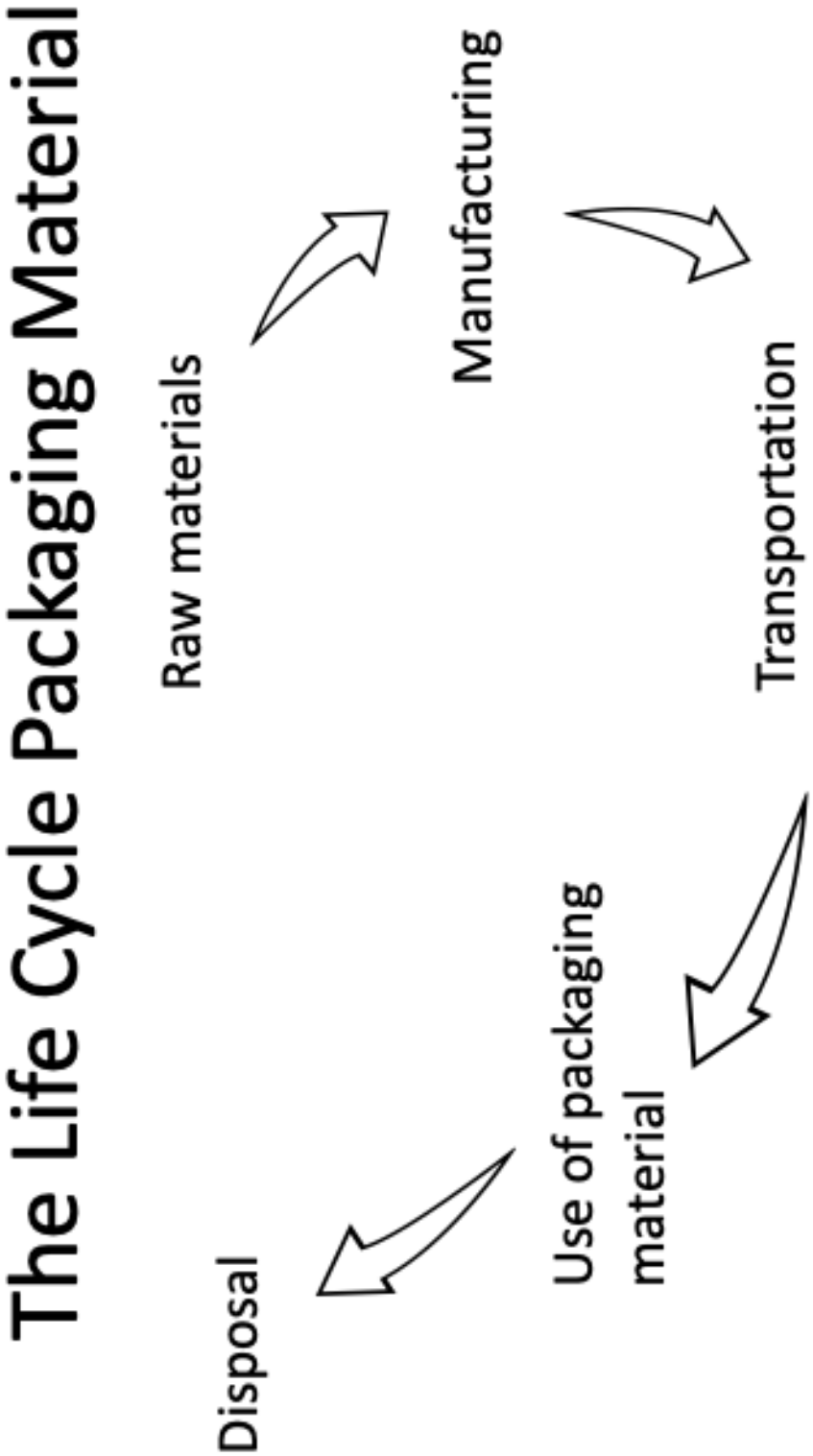

Partial life cycle assessment of polystyrene packaging
(Base Unit = 1 t polystyrene)
Raw materials
Extraction of raw materials
9,022 L
2.937 kg CO_2-e
Manufacturing
Making polystyrene packaging
1,849 L
0.324 kg CO_2-e
Transportation
Transport containers
Energy
21.514 kg CO_2 for 400 km (diesel truck, 40 L/100 km)
Assuming 2 ton per truckload
Use of packaging material
Disposal
Landfill (97 %?)
(Recycling)
Global warming potential
Water use
Data from
https://www.epsindustry.org/sites/default/files/LCA%20of%20EPS%20Resin%20LCA%202017.pdf
https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

Figure 2


The Life Cycle Packaging Material
Raw materials
Manufacturing
Transportation
Use of packaging material
Disposal


The Life Cycle Packaging Material
Raw materials
Manufacturing
Transportation
Use of packaging material
Disposal

V Conclusions

DIRECTIONS: Answer question 25 – 29 on a separate piece of paper.

25. Look at the two partial life cycle assessments you made with your group. List three features that surprise you or caught your attention and explain why you chose them.

26. From the information you gathered, can you conclude that one of the products you studied (the mycelium composite packaging or the typical material) scores better on the aspects you studied? Why or why not?

27. Can you find a scenario in which the mycelium composite packaging material scores better than the typical packaging material on the aspects you studied? If so, explain the scenario.

28. Can you find a scenario where the typical packaging material scores better than mycelium composite packaging material on the aspects you studied? If so, explain the scenario.

29. Follow the teacher's instructions to make a poster or a presentation with your group about your findings.

VI Closing Thoughts

DIRECTIONS: Answer question 30.

30. What aspects of mycelium composite material, life cycle assessment, or eco-friendly products intrigued you most? What are some aspects you would like to learn more about?