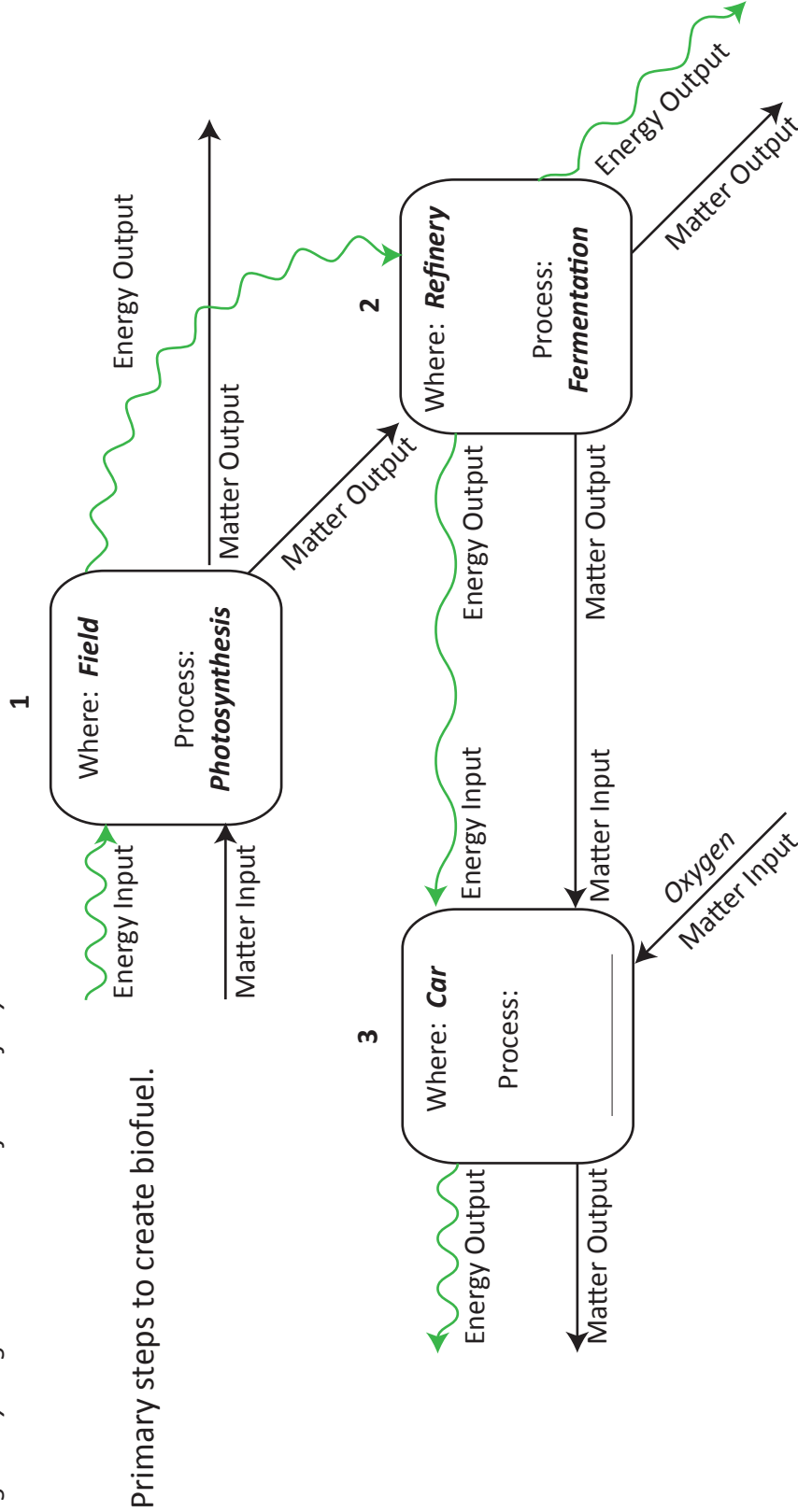


## Life Cycle Assessment Process Tool

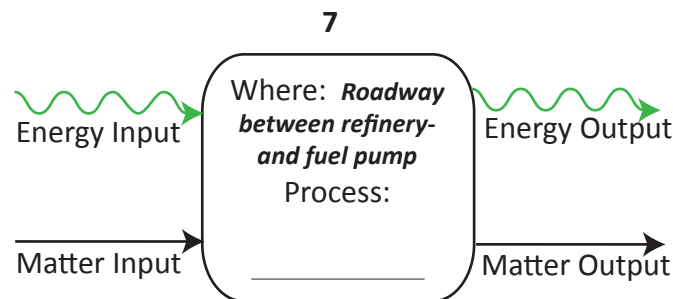
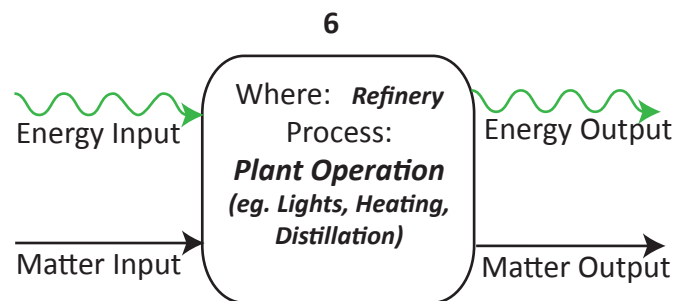
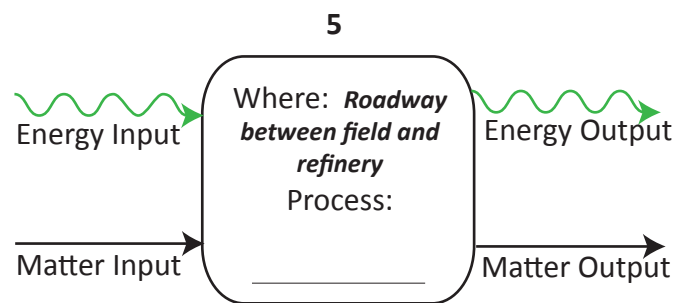
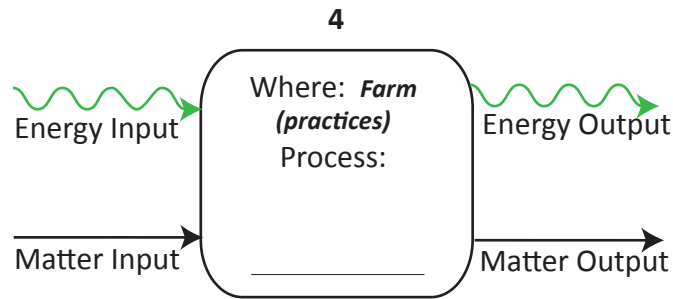
Demonstrate the flow of energy and matter through this system to make ethanol. Enter the correct energy input and output above the wavy lines and matter input and output above the straight lines. Pay attention to stages with more arrows than the others. Determine which inputs and outputs stay in the system and which “escape.” The first page follows the energy from the field to the refinery to your car. The second page shows additional inputs needed to create the fuel. Fill in the “process” occurring at any stage where it is not filled in for you.



Follow-up questions:

1. What is the relationship between the matter output from #3 to the matter input in #1?
2. Does all energy put into #1 make it to the energy output stage of #3? Why or why not?
3. If we are conducting a life cycle assessment for energy or greenhouse gases, like carbon dioxide, why can't we stop at stages 1-3? Why do we need to include stages 4-7 as well?

Additional inputs to create biofuel.



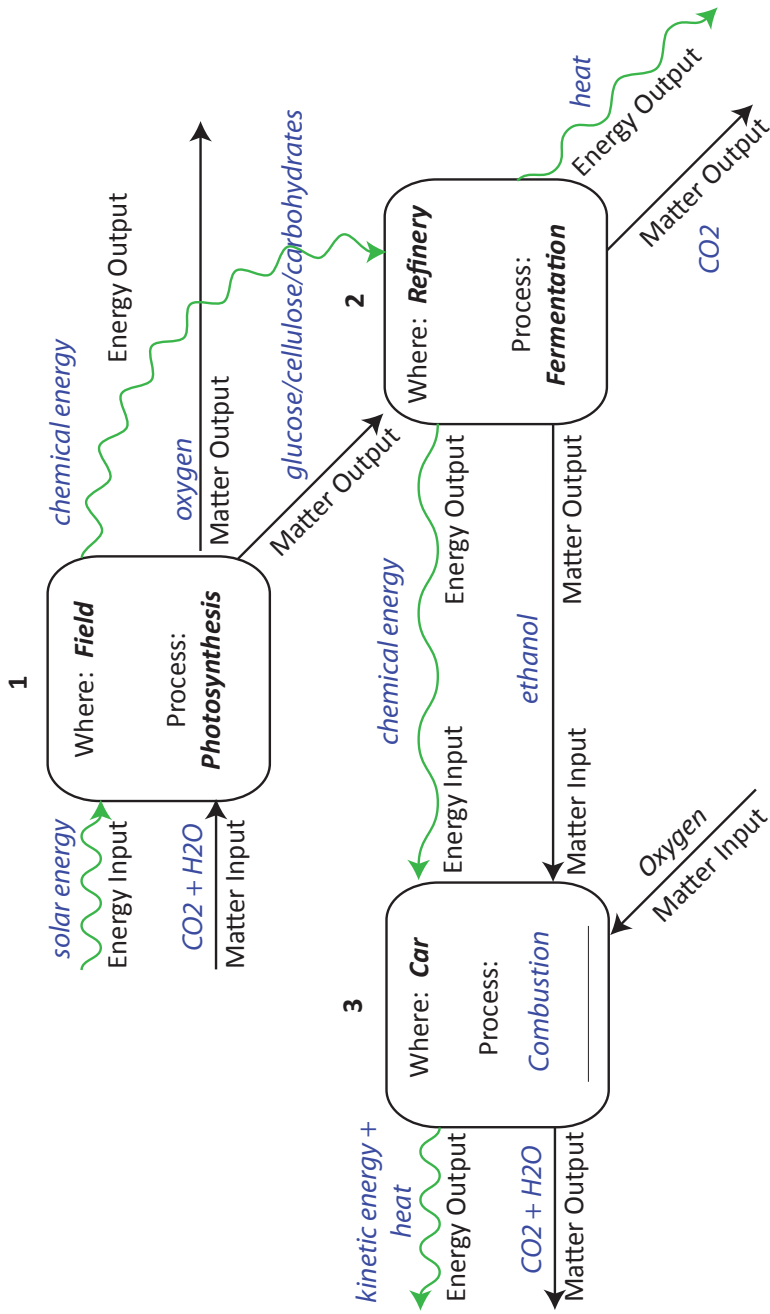
Follow-up questions:

1. Describe how you would determine the net energy gain or loss for ethanol production. Write an equation using only the relevant steps. You can abbreviate EI for Energy Input and EO for Energy Output (eg. EI #1 - EO #7=).

2. How do you think you could best improve the energy efficiency of this process? Reduce the carbon footprint?

# Life Cycle Assessment Process Tool

## Answer Key



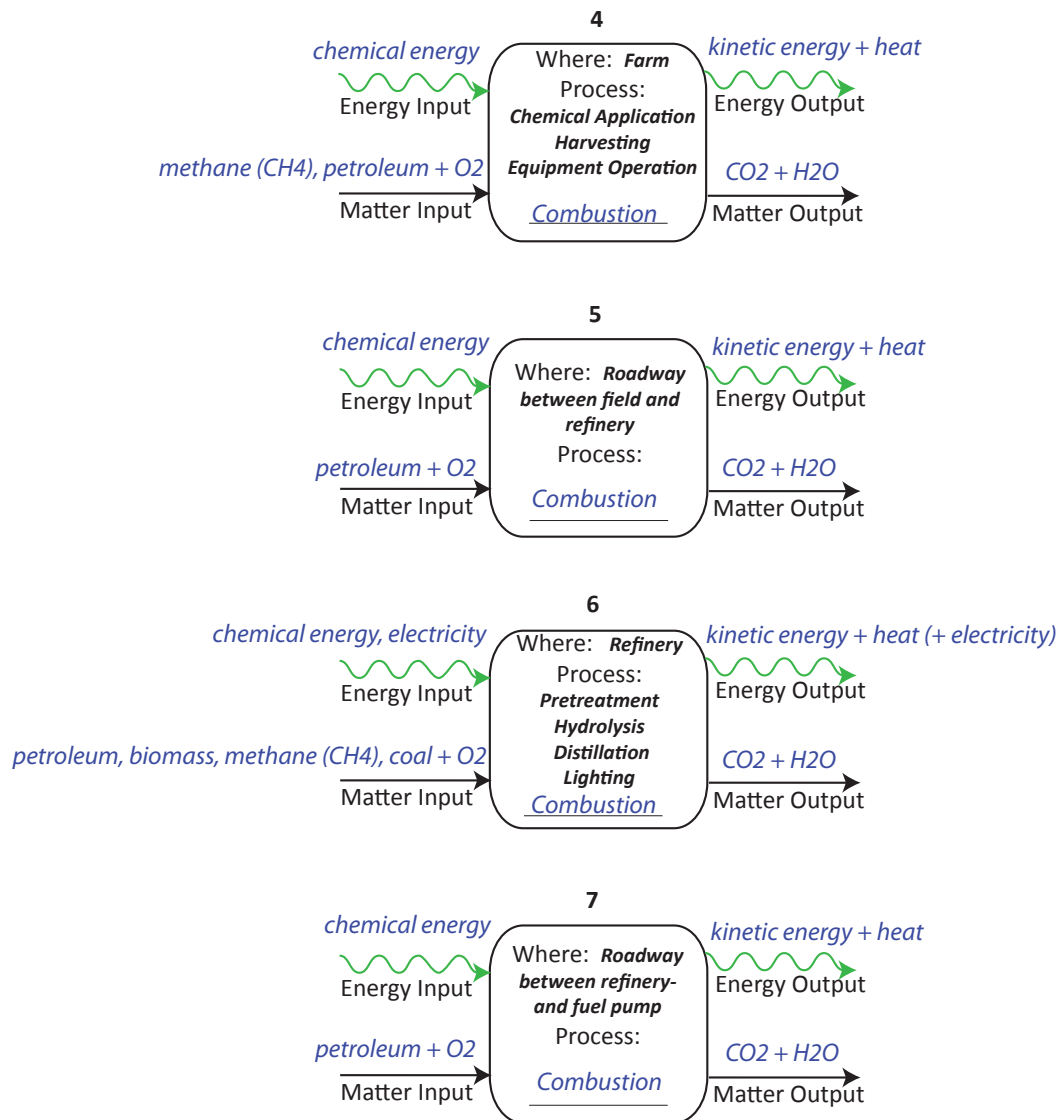
Please note that these answers show the primary energy inputs and outputs associated with fuel production. There are other energy losses in the system not shown here. Teachers could discuss the efficiency of plant growth and photosynthesis, energy content of CO<sub>2</sub> and H<sub>2</sub>O as well.

Follow-up questions:

1. What is the relationship between the matter output from #3 to the matter input in #1? They are the same. CO<sub>2</sub> leaving cars returns to the atmosphere where it could enter more plants through photosynthesis. This part of the loop alone is carbon neutral for that reason.
2. Does all energy put into #1 make it to the energy output stage of #3? Why or why not? No, much energy in the diagram is lost as heat or through organismal metabolism, like yeast, during fermentation (not modeled here).
3. If we are conducting a life cycle assessment for energy or greenhouse gases, like carbon dioxide, why can't we stop at stages 1-3? Why do we need to include stages 4-7 as well? Because more energy is needed to farm and move plants around, to actually run the refinery, and in other places. A life cycle assessment looks broadly at energy and matter inputs and outputs necessary to create the fuel.

Additional inputs to create biofuel.

**Answer Key**



*Note that answers for 4-7 will vary considerably. Fuel sources will vary for transportation use; refineries will often use multiple energy sources to power different parts of the refinery. For example, methane (natural gas) may be used to heat materials during pretreatment, but biomass may be burned to generate electricity or heat a fermenter. Some refineries generate enough electricity at this stage to sell excess to the grid.*

Follow-up questions:

1. Describe how you would determine the net energy gain or loss for ethanol production. Write an equation using only the relevant steps. You can abbreviate EI for Energy Input and EO for Energy Output (eg. EI #1 - EO #7=). *There are many ways to answer this question. Students should be reminded the energy in = energy out for the system. Net energy input is EI 1 - EI 4 - EI 5 - EI 6 - EI 7. (solar energy in minus fossil fuel inputs). Alternatively, engineers calculating a life cycle assessment might use EO 2 - EI 4 - EI 5 - EI 6 - EI 7 (energy in ethanol minus fossil fuel inputs to create it). Balancing renewables and non-renewables is a common way to look at the problem.*

2. How do you think you could best improve the energy efficiency of this process? Reduce the carbon footprint? *Energy: reduce losses to heat, shorten transportation distances, lower energy needs for conversion of fuel; Carbon footprint: increase energy efficiency, use of renewable energy for electricity, transportation, etc.*