CO_2 and Biofuel Transportation Adventure Race

Overview: In this lesson, students will be tasked with determining the best method of transporting slash from the environment to a pretreatment facility. Students will be given a choice of one of three transportation methods and then will go on their own "adventure race" that models their respective process.

Keywords

Slash pile- A pile of tree and understory mass (biomass) that is leftover from forest thinning or tree harvesting. A slash pile is woody biomass that is considered waste and has the potential to be transformed into biofuel.

Bin truck- A truck with a set capacity that can be used to transport condensed biomass that is still in slash form.

Mobile chipper- A device that can be filled and then loaded onto a truck or towed in some other fashion. It breaks the slash pile contents into wood chips that are denser and more compact than unaltered slash. Mobile chippers can also be used to process the slash pile at the slash site.

On road truck- A truck that will take the woody biomass to the pretreatment facility on non-graveled roads.

Chip van- A van used to carry chips from the slash sites to the road where an on road truck will carry them to the pre-treatment facility.

Grinder- A device that grinds up the biomass into a form that is more easily packed and resembles something like bark bits when it's been ground up.

Chipper- A device that takes slash biomass and breaks it down into wood chips. There are both stationary and mobile chippers (see above).

Bundler- A device that takes slash biomass and compresses it into bundles so that it is easier to transport.

Age / Grade Range: 6^{th}- 8^{th} Grade

Background: Given the advent of climate change, it is incredibly important to explore the viability of renewable energy. In fact, there are many different possible energy sources that have the potential to be tapped. For example, biofuel, a promising field of renewable energy, can come from anything from corn (ethanol) to woody biomass. However, processing the corn to make ethanol actually uses up more CO2 than burning ethanol instead of gasoline actually keeps out of the atmosphere.[1] Making biofuel from woody biomass instead of corn is an emerging process that has the potential to become widely used. However, it hasn't been tested as thoroughly as has ethanol production. Currently, groups such as the Northwest Advanced Renewables Alliance

[1] "Study Shows Ethanol Produces More CO2 Emissions Than Gasoline." EcoWatch. N.p., n.d. Web. 25 July 2015. <http://ecowatch.com/2014/05/02/ethanol-produces-more-co2-than-gasoline/>.

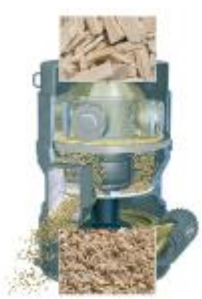
This work was supported by an Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.

(NARA) are investigating the potential of biomass created from forest "waste" as an energy source.

A critical step to determine if biomass can be successfully (both economically and environmentally) turned into biofuel on a large scale is to conduct a lifecycle assessment, which is an analysis of the emissions of all parts of a process (including machinery and co-products). This lesson takes a part of a lifecycle assessment conducted by Indroneil Ganguly and others at both the University of Washington and Oregon State University[2] that deals with the transportation of biomass from forest slash piles to treatment facilities. The research examines three different biomass transportation methods and measures both their acidification and CO_2 emission levels (although acidification isn't addressed in this lesson). The research seeks to provide hard data to answer a central question of NARA research: does the CO_2 output from the conversion process negate the benefit of biomass as biofuel?

One of the complications of the biomass transportation chain is that there are so many options that are possible when moving biomass from the slash pile to the treatment facility. Dr. Ganguly's research, and, as a result, this lesson, focuses on three transportation combinations: one involving a centralized grinder, one involving a bundler and then a grinder at the treatment facility, and one with a chipper at the slash site. The different methods of slash processing are outlined briefly below:

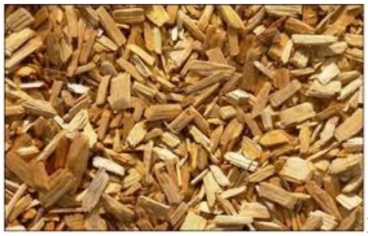
Grinder: The grinder is a machine that takes the woody biomass and grinds it up into smaller pieces that are denser and, therefore, easier to transport. By compacting the biomass, some of the air is removed, making the bundle weigh less overall.



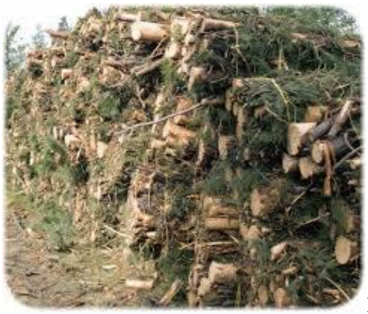
Picture: http://www.akahl.de/akahl/en/products/biomass_pelleting/pan_grinder_mill/

Chipper: The chipper chips the biomass up into small woodchips that, like the grinder, are denser than the slash pile and easier to transport.

[2] Ganguly, Indroneil, et al. "Modeling Transportation Logistics of Forest Residue Removal: A Life-Cycle Assessment." Infographic. *NARA Lifecycle Assessment*. N.p., n.d. Web. 25 June 2015.


Picture: http://growokc.com/collections/wood-chips

Bundler: The bundler bundles up the slash into logs that are around 80% denser than the slash itself.[3]


Picture: http://www.amandlaresources.com/renewable-energy.php

In addition to the selection of a grinder, chipper or bundler, the road texture needs to be taken into account as well, further complicating the selection process. To transport biomass, there are two main steps: on and off road. Off road takes place from the slash site to the highway, from which the slash is transported on-road in a truck. This lesson has the students modeling off-roading by hopping on one foot for the first half while carrying their own bins of "slash". The conversion of the lifecycle assessment data into a race allows the students to have a physical representation of the choices that go into sustainable biomass transportation. This experience allows students, after the race, to model and then analyze some of the current methods of biomass transportation and their environmental and economic impacts.

Next Generation Science Standards & Common Core:

Next Generation: NGSS MS-PS3, NGSS MS-ETS1, NGSS MS-ESS3

Common Core: ELA: 6-8.1C, 6-8.2A, 6-8.2D, 6-8.8; Math: 6.SP.5.a, 6.SP.5.b, 8.F.4, 8.F.5

Goals:

- To have the students understand the complications with biofuel transportation.
- To have the students understand the differences between types of machinery and the outputs they yield.
- To have the students understand the differences and realities behind

[3] "Gearing Up." Biomass Magazine. N.p., n.d. Web. 25 July 2015. <http://biomassmagazine.com/articles/5084/gearing-up>.

economic and environmental questions in biomass transportation. Students should conclude that one has to weigh both forces to come up with transportation that is sustainable but also economically viable.

- To have the students be able to think critically about which transportation method is the most economical (based on time) and is the most environmentally friendly (based on their own CO2 output).
- To have the students be able to expand upon this basic demonstration to answer questions whose scenarios they aren't as familiar with and understand what parts change the time and the CO2 output.

Objectives: Essential Questions

- What makes something use more CO2?
- What are some of the challenges facing biofuel developers?
- What does a lifecycle assessment do? Why is it useful?
- What method (between 3 outlined) is the most CO2 efficient?

Enduring Understandings

- The fact that sometimes environmental and economic factors conflict and the fact that scientists can't simply focus on what makes something the most environmentally friendly.
- Sometimes the cheapest option isn't the most sustainable.
- Biofuel transportation can be improved.
- Biofuel transportation is very situational and there is no one right answer.
- Transportation is just one part of the conversion process, so something that has more CO_2 emissions or seems less economically viable might be better for a different stage.

Materials:

- Recycling (probably about four or five days worth just to make sure); the amount can vary depending on how much you want to "transport" (ex. less for smaller kids). You can also use different types of scratch paper mixed in with the recycling to get as much "biomass" as possible.
- Plastic bins to represent trucks; each group needs a bin. These bins should be big enough that it takes multiple people to carry them.
- CO_2 measuring attachment for the Labquest (can instead measure heart rate with watch and counting)
- Timer/Stopwatch
- Two markers, one the halfway point and one for the finish. These can be anything from backpacks to flags.
- Worksheets

Set up:

This is an outside activity! The set up is as follows:

- Choose an area that is big enough that the kids can move from one side to another in a decent amount of time (no shorter than about 1 minute and 30 seconds). This can be anything from a field to a long hallway to a playground; it depends on what you have at your disposal. The only necessity is that all three groups use the same racecourse.
- Put bins at the starting line, with one for each group.
- Put a stack of newspaper or recycling at each starting line. It should be enough that it fills the bin completely. Keep recycling in bins until last second if it is windy. The paper should be crumpled up so that each page or half page is a loosely packed ball. It should look like it's crumpled up to be thrown away. If you're using recycling, as the lesson was when it was initially pilot tested, the recycling needs to be crumpled up to appropriately represent the slash piles.
- The course should have a designated halfway point and end point.
- Mark each point (beginning, middle and and) with a visual diagram telling the students what they have to do (if anything- this will vary by their diagrams and instructions). At the start line, there should be a picture of a heart and a picture of a watch. At the halfway point, there should be the number 1 followed by a picture of flat paper. Then, at the end, there should be the same picture of a heart and a watch. These

signs can be found in the worksheet packet.

- Students should hop on one foot for the first half of the race and then walk (not run!) the second half.

Classroom Time: One 50 to 60 minute class

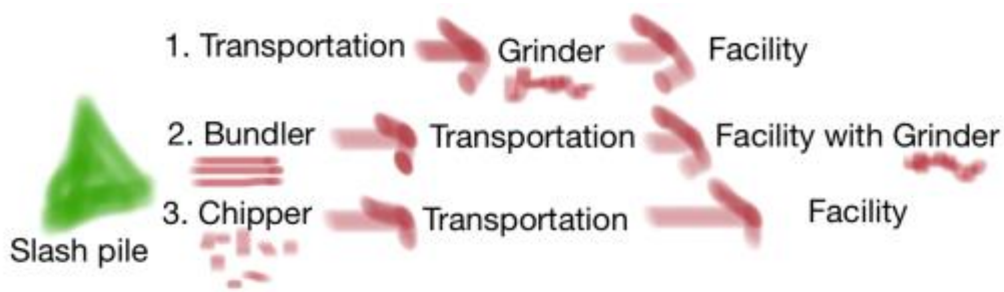
Introduction (Engage):

Students will be able to witness firsthand the varying CO_2 impacts of different methods of biofuel transportation through an adventure race. Students will be able to measure their own CO_2 output and have the opportunity to transform their very own biomass (newspaper or recycling). Students will then have the opportunity to apply their results from the race to solve other problems relating to biomass transportation.

To start, ask students basic questions about the transportation process to engage them in the discussion. See what they know about slash piles, grinders, chippers and bundlers (even if they are guesses) and write their answers up on the board. Then, have them read the following article: http://www.forestbioenergy.net/training-materials/fact-sheets/module-4-fact-sheets/fact-sheet-4-4-pre-processing-and-drying-woody-biomass/. This can be in groups, as individuals or all at once with the article projected on the board. This should take about 10 minutes.

Activity (Explore):

After the students have learned about the basic methods of transportation that are modeled in the race, they are ready to start preparing. Explain to the students that the races are based on 1.) a truck carrying the woody biomass to a stationary grinder then to a pre-treatment facility, 2.) biomass bundled at the site without grinding and then ground up at an off-site facility and 3.) a mobile chipper chipping at slash piles. Write a flow diagram on the board (suggestion like: the one below).



The students will then divide into groups based on which one they think will yield the least CO_2. Next, each group member will be given a worksheet (show below). They will circle their group number, fill out their hypothesis, and, with the instructor's help, record their starting heart rate. One member will be responsible for timing, and will record the total time the course takes. The instructor will double check with each group that they know what they have to do. Then, each group will draw a visual map of their course, labeling what they have to do and when/where.

After the groups have a chance to read over the directions and draw the racecourse maps on their sheets, the instructor will go around the room and have the students say exactly how their group will complete the race (summarize the instructions to prove that they know what to do). After all confusion has been cleared up, the race is ready to begin and everyone should go out of the classroom to the racecourse. When the instructor says go, the kids will begin their "biomass" transportation as assigned on the course. The groups are outlined as follows, and the students will be challenged to complete their tasks as quickly as possible. The instructor should announce that the bins should be no more than ¾ full. If they're more than ¾ full, the groups will have to take two trips/

Group 1 (the most intensive CO2)
<u>Start with:</u> crumpled up recycling next to a bin at the start line

1. At the start line, put the crumpled recycling ("biomass") in the bin *without compressing it* until it is ¾ full. The bins shouldn't be more than ¾ full so that the "biomass" doesn't fall out.
2. Group 1 should have to take two trips.
3. Carry the bin with the crumpled (but not compressed) paper to the marked halfway point.
4. Dump the biomass out and go back to the start line to collect the remaining biomass.
5. Once all the biomass is at the halfway point, flatten the crumpled paper. This represents grinding.
6. Carry bin (which should now be able to hold all the biomass) to the finish line.
7. Do 10 jumping jacks.
8. Timer records time and everyone records their end heart rate.

Group 2
<u>Start with:</u> crumpled up recycling next to a bin at the start line

1. At the start line, take the crumpled up paper ("biomass") and put it into the bin, compressing it as much as possible so that it is below the ¾ line. Make sure the biomass is thoroughly compressed and have everyone take a turn compressing until it can't be compressed any more.
2. Carry bin through halfway point and continue through until the group reaches the finish line.
3. Smooth the recycling crumples into flat at the finish line.
4. Do 5 jumping jacks.
5. Timer records time and everyone records their end heart rate.

Group 3 (the least intensive CO2)
Start with: crumpled up recycling next to a bin at the start line. For group 3, the recycling can be divided up into piles so that each member has their own mini slash pile.

1. At the start line, take the crumpled up recycling ("biomass") and have each member shred their own pile into the bin, by ripping each crumpled up piece into three pieces. Put the shredded biomass into the bin.
2. Carry the biomass through the halfway point to the finish line
3. Timer records time and everyone records their end heart rate.

Elaboration:

After the students finish the race and go back to the classroom, they will calculate their group average for heart rate *increase* and then write their average increase and their time on the board (following the steps on the worksheet). Once all groups have written their results on the board, the teacher will create a bar graph of both of them for each group so the students can compare the heart rates of the different groups as well as compare the heart rate value to the time value. The teacher will then explain (through questions and direct information given) that the heart rate corresponds to CO_2 output and time corresponds to economic value.

Note: for older students the teacher can create a xy plot with the x axis representing CO_2 emission (heart rate increase) and the y axis representing economic viability (time). Then the data can be analyzed using a line of best fit or other visual connections of the data points. If age appropriate, students can graph the data together in groups or on their own. The students will then use the data to determine which method releases the least amount of CO_2.

Evaluation:

The data that the students collect should follow this breakdown
Time

- Chippers are less expensive, so group 3 ideally has the lowest time.
- Bundlers are expensive, so group 2's time should be higher than group 3's.
- Group 1 has the longest distance to travel because they should have to take 2 trips on the first half of the course (to match the data from the lifecycle assessment) so they should have a number around group 2's and higher than group 3's.

CO_2 Emission:

- Group 1 should be the highest, followed by group 2 and then group 3.

If the data doesn't follow this pattern, that is ok. Discuss with students why these discrepancies happened. This could be either because students didn't follow the race rules (running instead of walking, for example) or because the race can vary by courses and isn't an *exact* match for the transportation process. If this turns out to be the case, ask students how they would improve the comparisons. This is an excellent exercise to judge how they have analyzed the different race tasks.

After the students know the actual hard data, they will be tasked with answering two follow up questions. The first question has to do with changing up the road surface. More specifically, the first question asks how the CO_2 emissions would change if there was more highway and less off-road transportation involved and why. Ask the students what about the race gives them their answer? The second question challenges the students to pick specific parts/machines in the transportation pathway that they think could be reformed or removed and why. What would they reform based on environmental standards? What would they reform based on economic standards? What's actually feasible?

Additional Resources:

- https://www.nararenewables.org/docs/one-pager/Environmental-Impacts.pdf
- http://www.extension.org/pages/70315/biomass-transportation-and-delivery#.VX0QVeugT8G

Sources:

1. "Biomass Transportation and Delivery." *Extension*. N.p., n.d. Web. 25 June 2015. <http://www.extension.org/pages/70315/biomass-transportation-and-delivery#.VX0QVeugT8G>.
2. Ganguly, Indroneil, et al. "Modeling Transportation Logistics of Forest Residue Removal: A Life-Cycle Assessment." Infographic. *NARA Lifecycle Assessment*. N.p., n.d. Web. 25 June 2015.
3. "How Is Biomass Transported?" *BioEnergy Consult*. N.p., n.d. Web. 25 June 2015. <http://www.bioenergyconsult.com/biomass-transportation/>.
4. "Study Shows Ethanol Produces More CO2 Emissions Than Gasoline." EcoWatch. N.p., n.d. Web. 25 July 2015. <http://ecowatch.com/2014/05/02/ethanol-produces-more-co2-

than-gasoline/>.

5. “Gearing Up.” Biomass Magazine. N.p., n.d. Web. 25 July 2015. <http://biomassmagazine.com/articles/5084/gearing-up>.