| Driving Question/Title: How can we “eat” Less water? (or) How might engineering different traditional meat alternatives reduce negative impacts on ecosystems? | | |
|---|---|---|
| Grade or Grade Band: HS | Discipline (LS, ES, PS): LS / ESS | Time: Three 1 - hour blocks / classes. |

**Lesson Level Performance Expectation (teacher-facing):**

Construct a model explaining how meat from non bovine sources (clean meat, beyond burger, impossible burger, vegetable burgers or chicken) can reduce negative impacts on ecosystems.

**Snapshot:**

High school students consider the amount of fresh water different activities require and figure out that most of the fresh water they are responsible for using up results from the food they eat and that different foods require considerably different amounts of water to produce. Comparing water consumption for traditional meat production to water consumption of meat alternatives leads students to answer the following driving question: How might engineering different traditional meat alternatives reduce humans’ negative impact on ecosystems?

By first brainstorming and ordering activities by relative water consumption and then engaging with data, students realize that the majority of freshwater use by humans can be the result of the production of the food they eat and that different foods require wildly varying amounts of water to produce. Students recognize that the production of meat is responsible for a lot of the water we use.

Students then construct a model to explain how / why the production of traditional meat replacement uses so much less water and as well how shifting to a traditional meat replacement might reduce impacts on an ecosystem.

People make decisions every day about the foods they choose to consume. As high school students, these young people are likely more empowered in making these choices than they have been in the past. Recognizing the environmental and societal impacts of the choices they make every day is important in understanding our larger place in society.

| Materials | | |
|---|---|---|
| **Student Materials**<br>Per Student<br>• Paper and pencil (for individual modeling)<br>Per Small Group (2 to 4 students)<br>• Chart paper<br>• Markers<br>• Access to the Internet for research | **Teacher Materials**<br>• Presentation (provided)<br>• Projector<br>• Chart paper<br>• Markers | **Resources for Building Teacher Content Knowledge**<br>• **Link to PBS lesson about limited freshwater on Planet Earth**<br>• **Link to more infographics about water use from UCLA (or we could put this at the end)**<br>• **Link to Wikipedia information about the Aral Sea**<br>• **Link to a detailed article about causes and consequences Aral Sea:** https://tidsskriftet.no/en/2017/10/global-helse/vanishing-aral-sea-health-consequences-environmental-disaster<br>• **Here is a 15 minute video about clean meat production:** https://www.youtube.com/watch?v=hBPNNVgD0SA&t=41s<br>• **Here is a detailed article about clean meat production and other ideas around clean meat:** https://www.aocs.org/stay-informed/inform-magazine/featured-articles/clean-meat-february-2018?SSO=True<br>• **Here is some information about Beyond Meat production compared to traditional meat production:** https://www.fastcompany.com/90241836/meatless-burgers-vs-beef-how-beyond-meats-environmental-impact-stacks-up<br>• **Here is a student friendly video about the Impossible burger:** https://www.youtube.com/watch?v=FjW2vNVZIhE |

**Phenomenon:** The phenomenon that students make sense of and eventually construct models to explain is the fact that the vast majority of the water that each person in the US is responsible for consuming comes from meat and that some meat requires a lot more water to produce than other forms of meat or meat substitutes.

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. | **DCI.A: Component**<br>• Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4) | **Crosscutting Concept: Systems and Systems Thinking**<br>• When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. |

**Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.**
**HS-ESS3-4**

**Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).**

**Assessment Boundary: none**

## Teacher Preparation

**Driving Question: How can different technologies and food choices result in less water use and reduce ecosystem degradation?**

**What Students Will Figure Out (Student Facing Objective)**

- Student Objective 1: Most of the water humans use is a result of food production (and consumption).
- Student Objective 2: Beef uses significantly more water to produce than chicken and non-meat substitutes because of the amount of feed converted to meat (compared to chicken and substitutes) and the movement of the water into and out of the different food production systems.
- Student Objective 3: Choosing low water use foods, especially clean meat and meat alternatives, can reduce our water use and mitigate some of the harm this might cause to ecosystems.
- Student Objective 4: Clean meat is an emerging technology that involves growing animal cells in a laboratory. It has the potential to greatly reduce many of the negative impacts of animal husbandry including greatly reducing water use and the number of animals raised for slaughter.

**Required Student Prior Knowledge:**

Students do not need to come into this unit with any specific prior knowledge. An understanding of the variety of ecosystems on Earth, how ecosystems function and of ecosystem services may be helpful when students are considering how changes in diet might preclude ecosystem degradation, but it is not necessary.

Stem cells are used in the production of clean meat. Teachers may need to fill in some gaps in student knowledge by providing a cursory overview of stem cells if students have not learned about these types of cells.

**Where might this lesson fit in my curriculum?**

This lesson would fit well into an ecosystems LS storylines and / or a storyline about global climate change. The standard has a lot of potential to be placed into a wide variety of storylines. Adding the contributions to greenhouse gas emissions (CO2, methane, effects of fertilizers and plowing, energy demands, etc.) that result from each of these food production systems to students' thinking and their models would create complex and nuanced challenges for students that could provide for rich classroom arguments and discussions and an opportunity to bring in some LS and PS PEs. This lesson could also lead into investigations around eutrophication especially as it relates to agricultural runoff. Ideas around GMOs and Roundup could also be brought into this conversation. Many of the meat alternatives (Impossible meat, for example) rely heavily on GM soy for production and GM yeast are used to produce the heme that gives the product its 'meaty' flavor.

This unit also lends itself to further investigation of impacts on ecosystems, particularly as it relates to excess water use. Students could construct arguments about which ecosystems might be most threatened by excess water consumption in a particular region or locally.

**Preparing for Student Models (Section 3)**

At the end of the unit students will be making their thinking visible by creating models of food production and resulting water consumption. There are many ways you might set this up in your classrooms. Here it is proposed that students create models that compare water consumption from beef production to water consumption from production of an alternative (including chicken). Depending on your focus and time constraints, you could have all student groups create the same comparison models, allow student groups to choose which system to compare to beef (which is how this lesson is written) or have student groups only model one system (instead of comparing) and have class discussions about similarities, differences etc. Alternatively, you could have students construct an argument about which meat alternative might have the greatest impact on a local ecosystem.

Regardless of how you approach the modeling, it may be helpful to come to a classroom consensus on what all student groups might want to include in their models. There is time built into the lesson for students to look at and learn from each others' models.

Systems and systems thinking should be explicit in the instructions to students. While explaining the task, emphasize the need to define the systems in the models and as well to quantify as best they can relevant inputs and outputs. These might be decided on as a class prior to the modeling as well.

**Additional Information**

Additional graphics that were developed but that are not a part of the lesson are included at the end of the Google Slides presentation. You may find these useful or develop other engagements based on these infographics.

## Experience the Phenomenon

**Summary:** In this section students will first briefly engage with a model as a means of introducing the concept of freshwater scarcity. They will then brainstorm, aggregate and rank various activities according to the amount of water students imagine each uses / requires. After this original thinking, students will analyze data about water use, including some information about the water necessary to produce certain foods. From this data analysis they will recognize that the vast majority (80 - 90%) of the water humans use is a result of the food we eat.

1. **Engage students with the PBS Learning Graphic comparing amounts of water on Earth. This first engagement is meant to establish available freshwater as a limited and scarce resource.**

**Initial engagement with the model:**

Project the image of the Earth with the three spheres of water superimposed. Do not yet share the accompanying text. Ask students to notice and wonder about the image. What do they think the three spheres might represent? After a few minutes, ask for a few students to share their thinking. Encourage students to explain their thinking about their science ideas. Was there anything in the image that they might be able to point to that supports their ideas? Provide opportunities for some whole class productive science talk. You might ask questions such as …

**Suggested Prompts might include:**

- What do you think the different spheres in the image might represent?
- Does anyone agree or disagree? If you are willing to share, please be prepared to explain *why* you might agree or disagree.
- Does anyone have a different interpretation of the image?
- Does anyone else have a similar or the same interpretation but perhaps for a different reason?

**Some things students might notice / possible comments:**

- There is no water on the Earth.
- I'm pretty sure it is the Earth because I can see the continents.
- I think the three spheres are made of water because they look like water. But I'm not sure why there are three.
- Maybe there are three spheres because there are three different types of water on Earth - like salt and fresh and in between.

It’s not important that the class arrives at the correct interpretation, only that they try to make sense of the information. Share the accompanying text on the next screen and ask students to discuss the ideas with an elbow partner. Give them an opportunity to ask one another questions and/or ask for clarification. You may want to put forward the remaining questions on the slide.

- What might the purpose of the image be? What do you think the person who created this image had in mind?
- This image is based on data from 1993. Do you think the infographic still accurately reflects the distribution of water on the Earth? Explain your reasoning.
- What percent of the larger sphere do you think is represented by the medium sphere? The smallest sphere?

The image is intended to help people better understand just how little freshwater, and more specifically *available* freshwater, there really is on planet Earth. This first engagement is meant to establish available freshwater as a limited and scarce resource.

Share the third slide of pie charts with students and give them an opportunity to process it - first alone and then in pairs. The 20% found in groundwater is in the form of soil moisture and groundwater in aquifers too deep to be accessible. This water is not water we can use.

The water that is available to humans for use is the water in lakes and rivers - a little over 50% of the total of the third pie. Water available for human use makes up about 1% of all water on Earth. This is the idea we want students to understand.

**Suggested Prompts include:**

- Does each pie chart correlate to one of the spheres in the first image? (The first two pies do correlate to the first two spheres, but the last sphere represents lakes and rivers only - a small portion of the third / bottom pie)
- Does each pie chart total up to 100%? If so, 100% of what? (All water / fresh water / fresh water that is not inaccessible groundwater or water captured in glaciers and the ice caps)

**2. Students brainstorm and rank those aspects of their lives / activities by the amount of water each consumes. Students will then make sense of data about these ideas. This second engagement is to help students figure out that the vast majority of the water they are responsible for consuming is a result of the food they eat.**

**Making sense of water use data:**

Ask students to consider what activities they might engage in that use the most water over the course of an average day. Help students recognize that we are referencing a daily average. Have each student, in their alone zone, write the five activities they engage in that they think use the most water. When everyone is finished, have students work with an elbow partner to co-construct a new list of the three items they think use the most water. This time ask each pair to rank their three items from “uses the most water” (3) to “uses the least water” (1).

Come to a class consensus around the top three activities from the students’ paired lists. Ask one group to share their list. Write this on the whiteboard. Ask a second group if they had any activities on their list that did not show up on the first pair’s list. Add these. Ask the rest of the class to complete the list by asking for any other activities that haven’t shown up yet on the class list. You shouldn’t end up with a list of more than six activities. Ask each pair to send one student up to the white board with their list and write the rank number after each item. If they did not have the item on the list, they should write “0.”

You will end up with something like this:

Showering 3, 3, 2, 3, 0, 1, 3 …

Brushing teeth 2, 3, 2, 1, 1, 0, 2 …

Toilet 1, 0, 0, 1, 2, 3, 1 …

Washing Dishes 0, 0, 1, 3, 1, 2, 1, 0 …

Etc.

Quickly determine totals. Based on these, construct a class consensus “Top three activities that consume the most fresh water.” The higher the total, the higher up on the class list.

Share with students that you have some data that we can investigate to see how our predictions line up with current research about water use and those activities that use the most water. Ask students - in those same pairs, to compare the information in the data set with their list (or the classes co-constructed list). How close were predictions to the data? Is there anything on the list that they might find surprising?

Give students a few minutes to make sense of the information and compare the data to their lists. Guide students through a conversation about the information they have in front of them.

**Suggested Prompts include:**

- Which activities are responsible for the use of the most gallons? The fewest?
- What aspect of water use were you perhaps not taking into account?
- If a coke is only 335 ml (or 12 ounces), how is it possible that drinking a coke results in the consumption of 1256 L or 33 gallons of water?
- Are there any activities that use more water than eating any of the items on this list?

From the information students have (which is admittedly not much), ask student pairs to confer with one another and make a guess as to how much of a person's total water consumption is a result of the food they eat (compared to all of the other activities that we have been considering). Ask for volunteers to share their thinking and explain their reasoning.

On average, the amount of our freshwater water use that is attributed to the food we eat is 90%. Once a number of students have shared their ideas and thinking, share this information with them verbally, by writing it on the whiteboard or by using the slide provided. Encourage students to make sense of this idea. At this point, it might be helpful to allow students to ask each other questions about this concept in order to better make sense of it. Some students will struggle with the abstract concept of "eating water." We will explore these ideas and further make sense of the concepts in the next section.

**Additional Guidance:**

This is where the data came from for the breakfast data for the sorting engagement:
https://www.climatechangenews.com/2012/03/22/world-water-day-how-much-water-do-you-use-in-a-day/

**Differentiation:**

Not all water "use" is the same. A lot of the water we use is withdrawn, but becomes available again for use by others downstream of us. Some water, however, is 'consumed' and not available for immediate use by others. Some students may be prepared to wrestle with these somewhat abstract differences and bring them into their thinking now - and perhaps even into their modeling later.
http://environment.umn.edu/news/were-not-running-out-of-water-a-better-way-to-measure-water-scarcity/

## Investigate the Phenomenon

**Summary:** We recognize that most of the freshwater we are responsible for consuming is a result of the food we eat. We want to investigate which foods require the greatest amount of water to produce.

In this section students will work with data about a variety of foods from McDonalds to figure out that, generally speaking, meat requires a great deal of water to produce and that some types of meat require more water than other types.

Students brainstorm ways we might mitigate water use and as well consequences for humans and ecosystems if we continue on our current water use and population trajectories.

Students then watch a video about clean meat that introduces them to this phenomenon (clean meat grown from animal cells in a lab).

1. **Students work in pairs to identify patterns in data about different types of foods and the amount of water it takes to produce each. This first engagement is to allow students to figure out that meat takes more water to produce than non-meat and that some meat (beef) takes more water to produce than other types of meat (chicken).**

**Students generate claims about patterns in data about water used in the production of several McDonald's menu items.**

Share with students that now that we recognize so much of the freshwater we are responsible for consuming is a result of the food we eat, we are going to try to figure out which foods use more water to produce and which might use less. This first brief whole-class engagement is to ensure that all students understand the data they will be working with. Project the image and data about chicken nuggets. Give students a few moments to make sense of the information provided. Have them check in with an elbow partner to share any initial noticings and wonderings. Perhaps their partner can answer a question they might have. Have a group discussion to make sense of the information provided. Ask students to share any observations they might have. We need to be certain students understand that the 38 indicates that it takes 38 gallons of water to produce the 4-piece Chicken McNuggets. Continue the discussion until all of the information in the data has been addressed by the class. You may need to prompt your students, "Why might it be important to include information about "per calorie" water use information and "per gram of protein" water use information?" We want students to understand that these are all useful ways to compare different foods. Sometimes we may want to consider total water consumption, while other times we may want to think about the amount of water use per unit of energy. Remind students that a calorie is a unit of energy and that the calories indicated on our food labels are actually kilocalories. Students may wonder why the “per gram of protein” information is provided. Remind them of the important role that proteins play in living things and certainly in our bodies. Thinking about how much protein a particular food provides can be helpful and that a diet lacking adequate protein can result in serious health consequences. A person may consume enough calories, but if enough of those calories are not protein, they may still be malnourished (while not being undernourished). Students should now be ready to engage with the full set of data about the water necessary to produce a variety of foods from McDonald’s.

Provide student pairs with the sets of data about a variety of foods from McDonald’s. Prompt students to identify patterns in the data to use as evidence in making claims about relationships between water consumption and different foods. Ultimately, we want students to arrive at the conclusion that meat takes considerably more water to produce than other food products. Encourage students to be specific in their claims. They should be referencing either total balance, gallons per calorie or gallons per gram of protein when making their claims. Encourage student pears to come up with at least three claims about food as it relates to water consumption based on patterns they identify.

Possible claims might include:

- Food items with beef require significantly more total gallons than food items without beef.
- Foods containing meat require more total gallons than food that does not contain meat.
- Foods containing chicken require fewer gallons per calorie than foods containing beef.
- Foods that do not contain meat require fewer gallons per gram of protein than foods that do contain meat.

Once all groups have made at least three claims, have the person sitting to the left in each group stand up and sit with a different partner. In their new pairs, students should share claims with one another challenging their new partner to find the patterns in the data that support the claim each has made. Once students have had an opportunity to share and claims have been vetted for evidence, ask for volunteers to share some of the claims that they came up with.

The following are the larger ideas that we want students to arrive at based on the data:

- Regardless of the parameter, foods that contain beef require more water to produce than those containing chicken.
- Foods that contain beef require more water to produce than those containing no meat at all.
- Those food items that contain chicken require more water to produce than those containing no meat at all.

- Foods containing more beef require more water to produce than those containing less beef.

You may choose to record these larger ideas on a piece of chart paper or temporarily on the whiteboard.

2. **Students brainstorm ways we might mitigate water use and as well consequences for humans and ecosystems if we continue on our current water use and population trajectories. This second engagement is to help students connect fresh water use to impacts on humans and the ecosystems that support them. Students are also introduced to the concept of lab grown ("clean") meat.**

**Students consider ramifications for overexploitation of freshwater resources and are introduced to the concept of lab grown meat (Clean Meat).**

This would be an appropriate opportunity to take stock of what we have learned so far. You may choose to track these ideas on an anchor chart or whiteboard. In our first engagement, we established that there is, relatively speaking, very little fresh water on planet Earth available for use. We also realized that most of the water humans are responsible for using is a result of the food we eat. In this second engagement we have figured out that some foods – meat in particular – require much more water to produce than foods that do not contain meat. What we have not yet considered, however, are some of the ramifications of overexploitation of our freshwater resources.

Share the slide of the Aral Sea before and after and give students some time to make sense of the information. Allow them to make and share observations and questions with an elbow partner and then as a class. You can find background information about the Aral Sea here: Aral Sea - Wikipedia and there is a succinct and detailed article about the causes and consequences here: The vanishing Aral Sea: health consequences of an environmental disaster | Tidsskrift for Den norske legeforening. Ask students to consider the three questions included in the slides presentation:

- What might have caused the sea to decrease so dramatically?
- What ecological consequences might have resulted from this dramatic change?
- What consequences do you think there were for people living in the region?

Have students share their thoughts with an elbow partner. At this point you may choose to have a class discussion about possible causes and effects before moving on.

Watch the video clip linked to in the presentation of the Vagabrothers visiting the Aral Sea. The segment is a little less than three minutes long. The next two slides cover some of the main ideas about ecological effects of the disaster as well as some of the effects on people in the region. While this lesson focuses on the amount of water that is used in the production of beef, the Aral sea disaster was a result of poor resource management for agriculture - primarily water for growing cotton. Students may need help clarifying these distinctions as the lesson progresses.

The next three slides show examples of bodies of water in the US that have been shrinking. While the Aral Sea is geographically far away and may seem like it happened a long time ago, these current examples from the US should bring a relevance and urgency to this issue of water use.

Show the image of the projected global meat consumption and ask students to make sense of the information in the graph. Ask them to share noticings and wonderings with an elbow partner. Have students consider why the amount of meat being consumed continues to rise steadily over time. You may wish to have a class discussion around noticings and wonderings as well as this question. We want students to recognize that, in addition to the increase in global population driving the increase in consumption, many people are rising out of poverty. As a result they are able to afford to eat more meat. Return the thinking to the topic of water use as a result of meat production and consumption. You may simply ask students what impact this meat consumption might have on our freshwater resources. Continuing to produce and consume meat the way we have been certainly seems unsustainable.

Understanding these relationships between our freshwater supply and meat consumption ask students, in their alone zones, to generate a list of at least three ways we might mitigate freshwater use that results from meat consumption. Student ideas should be specific ("reduce the amount of water we use to grow plants for livestock," for example, rather than "use less water"). Ask students to share their lists in groups of three and identify the three they think would be most effective and result in the greatest reduction of freshwater use. Have each group send one reporter to the whiteboard to list each of the three mitigation approaches. Have a class discussion around these ideas, allowing opportunities for students to ask questions of one another regarding their reasoning behind the ideas they generated. If you choose, you could aggregate the responses and identify those three that the most groups mentioned.

Some possible student ideas are:

- Reduce the amount of water we use to grow plants for livestock
- Eat less meat

- Eat veggie burgers
- Eat more chickens and fewer cows
- Waste less food in general

The rest of the lesson will focus on understanding meat alternatives and the ways they can be leveraged to address our freshwater resource challenges. Have a discussion with the group around the concepts they have identified as a way to move the lesson forward. You may ask questions like these:

- Is it realistic to expect people to stop eating meat? To eat less meat?
- Are any of you vegetarian? vegan?
- How many of you have had a veggie burger? A beyond meat burger or an impossible burger?

It is unlikely that students are familiar with the concept of meat from lab grown animal tissue. This meat is now being referred to as "clean meat" and will be available to consumers in the very near future. As a means of introducing this concept, project the graph titled "New Meat for the World." Ask students to make sense of the information and share their noticings and wonderings with an elbow partner. The question about what cultured meat is will undoubtedly arise.

Share the infographic titled "Two in three US adults would try meat grown from animal cells." Give students the opportunity to process the information. There are a lot of ideas presented and in varying forms. Placing students into groups may help students process the information. Engage the students in a classroom conversation and elicit the main ideas in the infographic. You will likely want to structure the conversation around the three main sections in the graphic. You may choose to have student groups construct one sentence summaries for one of the three sections and have them write these on the board.

Share the infographic titled "Production Stages of Clean Meat." While it is not the most scientific treatment, it will allow students to get some idea of the process. Depending on what students have learned already this year about cells and / or stem cells, the teacher may need to provide some background information.

Show the video included in the slide show at the end of this section. It's 3.5 minutes and summarizes a lot of what students have figured out over the course of the lesson so far. It also brings in new ideas like the role that raising animals plays in increasing greenhouse gas emissions and the animal welfare argument for clean meat and meat alternatives. Give the students a few minutes to talk through main ideas with a partner. You may want to have a brief class discussion perhaps focusing on some of the potential benefits of clean meat.

If you have been using an anchor chart or tracking new learning on a whiteboard, this might be a good time to revisit your class thinking and add some new understandings.

**Additional Guidance:**

Here is a 15 minute video about clean meat production: https://www.youtube.com/watch?v=hBPNNVgD0SA&t=41s
Here is a detailed article about clean meat production and other ideas around clean meat: https://www.aocs.org/stay-informed/inform-magazine/featured-articles/clean-meat-february-2018?SSO=Tru
Here is a student friendly video about the Impossible burger: https://www.youtube.com/watch?v=FjW2vNVZIhE

## Explain or Model the Phenomenon

**Summary:** We recognize that consuming less meat, different types of meat or meat alternatives could have a significant impact on the water that humans use and some of the consequences of not changing our water use paradigm. We want to understand exactly how these changes in meat production result in less water use.

In this section, students will co-construct and share explanatory models detailing how/why these alternatives use so much less water to include some of the positive downstream effects these shifts might have. We want students to keep the crosscutting concept of systems and system inputs and outputs at the front of their thinking as they construct their models. While explaining the task, emphasize the need to define the systems in the models and as well to quantify as best they can relevant inputs and outputs. These might be decided on as a class prior to the modeling as well.

1. **Students construct models in small groups.**

   Now that we understand the relationship between water use and the foods we eat, we want to make sense of why these foods require such very different amounts of water to produce.

**Initial Models and brainstorming**

Challenge students to make sense of water use required to make a hamburger by asking them to construct a rough draft of an explanatory model of this phenomenon in their alone zone. Encourage them to indicate all points in the system where they think water might be a necessary input. Have them consider the following questions:

How might they best quantify that water use?

How might they best indicate where the water is going as it leaves the system?

Give them about five minutes to do some initial thinking and brainstorming, and then move them into small groups or pairs.

**Co-constructing models in small groups**

There are many ways you might approach this depending on your larger storyline, time restraints and students' prior experience with the practice of modeling. Student groups should co-construct models that serve to compare two systems. You could assign these systems to different groups or you could allow students to choose. Models should focus on explaining why the water use of the two systems is so different and should include data from research that students do about each system as they work. Models should also include potential positive effects of less water use and potential negative impacts of excess water use in the traditional beef production system. Ideally, every group will have at least one other group comparing (and therefore researching) the same two systems so student groups can learn from one another. If students are relatively new to the practice of modeling, you might ask all groups to compare the same two systems.

Examples of systems that students might compare include:

- Production of a conventional hamburger to production of a Clean Meat burger
- Production of conventional hamburger to production of a chicken burger
- Production of conventional hamburger to the production of an Impossible Burger or Beyond Meat burger

- Production of conventional hamburger to the production of a veggie burger

Encourage students to make comparisons across the two systems especially as their models relate to water use. It may be helpful to remind student groups throughout the process that, while they will have to include various aspects of different processes for burger production, the goal of the models is not to explain the process itself but to explain and compare the water use required. Models should therefore be identifying points in each system where water is an input. Some information may be more challenging to find and some information students find may be technical.

2. **Students learn from and provide feedback about other groups' models and modify their own models accordingly.**

   Students will provide positive and constructive feedback to other groups and as well gain information and ideas to bring to their own models.

**Students provide feedback to other groups**

Once student groups have made significant progress towards finishing a first draft, explain that they will be providing feedback to other groups and receiving some feedback of their own. The purpose of the feedback is to highlight effective aspects of the models and to help groups understand how they might improve the effectiveness / explanatory power of their models. Give student groups sticky notes in two colors - one color that they can use for highlighting effective approaches (or just things they really like) and another color to use to help other groups recognize what aspects of their models might be unclear. Groups should also be looking at what aspects of other groups' models they might want to bring to their own models to improve them. This holds true for information they see on other models as well. The number of groups each group can visit will depend on time. Ideally each group will at least be able to engage with a model from at least one group that is doing the same comparison as they are.

Depending on the larger scope of the storyline, you may ask students to include some of the ideas they encountered in section 2 around the ways reduced water use benefits local ecosystems. Challenging students to include relative estimates of impact mitigation for one identified impact could bring data analysis and size and scale into the model. Additionally, if appropriate, students could consider water use in their local ecosystems when thinking about impacts and bring these ideas and research into their models.

**Students complete final models**

Students revise and complete final explanatory models based on peer feedback and ideas that they gleaned from other models they evaluated.