Agrivoltaics Scenarios

The Pros and Cons of Using Land for Agricultural and Energy Production

Description

Students will be introduced to agrivoltaics, the dual use of land for agricultural and energy production. They will analyze the pros and cons of adding solar panels to farms and ranches in different locations and with different agricultural products.

Grade Level: 6-8

Objectives

Students will:

- Investigate a farm/ranch scenario, keeping in mind their criteria for success (producing good agricultural products, making a profit, and not harming the community).
- Determine the pros and cons of adding solar panels to their farm/ranch.
- Decide what other information may be needed to help make this decision.

Time: 50 minutes

Common Core State Standards

ELA-LITERACY.WHST.6-8.1.b Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.

ELA-LITERACY.WHST.6-8.2.d. Use precise language and domain-specific vocabulary to inform about or explain the topic.

ELA-LITERACY.WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.

Next Generation Science Standards

MS- ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems	ETS1.A Defining and Delimiting Engineering Problems	Cause and Effect Influence of Science, Engineering, and Technology on Society and the Natural World

Materials

- PowerPoint presentation and a way to show it to students
- Farm Scenario Sheets
- Student worksheets
- Potential Answers sheets for all scenarios (for teacher use only)
- Group discussion pros and cons poster
- Sticky notes (4 different colors)

Background

According to the U.S. Department of Energy, 4% of US electricity is currently provided by photovoltaics (solar panels). If the US were to increase that number to 40%, the solar industry would need to take up at least 5.7 million acres, which is 0.3% of U.S. land (U.S. DOE, 2023). This doesn't seem like much, but not just any land will do. Solar panels require flat, open, and sunny land that is near transmission lines. These ideal locations tend to be just outside of cities and towns. This means large scale solar plants are competing for the same land used for farms and ranches.

To solve this conflict, countries like Japan and Germany have spent the last decade researching and implementing agrivoltaics. Agrivoltaics is the combination of agriculture and photovoltaics. It is a dual land-use solution where solar panels are designed to be put above crops and ranchland. The U.S. has also recently begun to research agrivoltaics as a solution for our energy needs. Initial research shows potential benefits for both our energy needs and our farms and ranches, but more research is needed.

Agrivoltaics is an active area of study that is relatively new to the United States:

- In Plains, Georgia, solar panels have been installed on land once owned by President Carter. Under these panels, they've established pollinator friendly plants to renew lost pollinator habitats and deal with stormwater runoff issues that can be caused by solar farms.
- At Michigan State University, sheep are an effective way to manage the growth of vegetation under solar panels as scientists research the impacts on the sheep industry within the state.
- Since 2019, the University of Arizona has been successfully growing tomatoes and peppers under solar panels at the Biosphere 2 site.
- Scientists at the University of Minnesota are researching the effects of shading milk cows under solar panels.

Some of the potential benefits of agrivoltaics for agriculture include providing cooler microclimates under panels for plants and livestock and increasing water efficiency of crops in more arid states. Agrivoltaics could also help address the heat islands that can be created under large solar installations. Plants under solar panels could help to mitigate this problem for the solar industry. This would also help the solar panels produce more energy since solar panels become less efficient in hot temperatures.

Farmers and ranchers could also benefit from agrivoltaics systems. For example, they can make additional profit off the energy produced on their farms. This could help farmers and ranchers diversify their income streams.

However, solar panels are expensive, and the cost of installation may increase for farmers and ranchers who need to put panels high enough to avoid damage from livestock and crop processing needs such as tractors. This may make the cost of solar panel installation unrealistic for many. Also, the level of acceptance for solar panels and government support for installation varies from state to state. These are some of the concerns being addressed by the U.S. Department of Agriculture.

Agrivoltaics is not a one-size-fits-all concept. Many variables affect a farmer's or rancher's decision, from the source of income for a farmer or rancher, local energy needs, and even local laws on land-use. This lesson is designed to introduce students to agrivoltaics and help them consider some of these potential benefits and limitations in the decision-making process for agrivoltaics adoption.

Preparation

1. Place the poster up in an easy-to-access space.
2. Set up the computer and PowerPoint.
3. Plan to have students work in pairs for the activity portion of the lesson.

Teaching Guide

Introduction to Agrivoltaics (~10 minutes)

1. Slide 2: Ask students what solar panels do and where they may have seen them. Explain that solar panels convert sunlight into electricity. Let students know that in today's lesson, they will be looking at how solar panels could be used by farmers and ranchers.
2. Slide 3: Prior to starting the video, tell students to pay attention to how it explains the term **agrivoltaics**. Ask them to think about how agrivoltaics is being used by the farmer in the video.
    a. Play the five-minute video: "Agrivoltaics: Solar Panels Bring Life to Struggling Farms" by Now This: https://youtu.be/u_hRm-WFM1M?feature=shared
    b. Based on the video, ask students to define agrivoltaics. Agrivoltaics is the dual use of land for agricultural production and photovoltaic (solar energy) production.
    c. Today's lesson will look at scenarios where agrivoltaics might be used in the U.S. and consider the pros and cons of shifting traditional farms and ranches to agrivoltaics.
3. Slide 4: The U.S. is considering dual land use because solar panels take up space, and that space competes with farms and ranches.
    a. Solar energy production needs a lot of space. Solar panels can only produce about 10 watts/meter^2.
    b. To give perspective, share that the average household uses ~2,500 watts a day. It takes about the space of 26 full-size beds, side-by-side, to run a house on solar panels.
    c. But not just any land works. It needs to be flat, open, sunny, and accessible to a city's grid via transmission lines. Many of the ideal areas for solar farms are already being used by farmers and ranchers. Some people feel the agriculture and the solar industry are having to compete for this land. Agrivoltaics could support both.
5. Slide 5: Agriculture is such a diverse industry, and there are many ways agrivoltaics could be implemented. Farmers could put them over or around different crops. Sheep and cattle could graze under them. Even pollinator habitats could be established beneath them.
6. Slide 6: There are also many ways solar panels could be installed.
    a. They could be placed directly over the crops. This works best if you want the crops to be shaded during the day.
    b. The panels could be placed in alternating rows. This works best if you don't want as much shade and have the space to place the solar panels.
    c. They could be mounted at different angles and could even be placed vertically as a barrier. Different angles could impact how much light is being converted to energy.
    d. The panels could be placed on higher or lower frames, depending on the needs. It's good to keep in mind that taller frames mean more material costs.
    e. There are even panels that can be mechanically rotated to the angle needed. This could mean larger farm equipment could be used beneath them, or it could track the sun through the day. However, these systems are much more costly.

7. Slide 7: Because there are many ways agrivoltaics could be implemented and installed, there are many variables to study through scientific research. Scientists at New Mexico State University and the U.S. Department of Agriculture's Southwest Cotton Ginning Research Lab and Jornada Experimental Range are actively researching agrivoltaics in Las Cruces, New Mexico.

Arizona Cherry Tomato Scenario (~12 minutes)

1. Slide 8: Tell students that today they are going to be farmers and ranchers trying to decide whether they should add solar panels to their farm or ranch. The first scenario will be done together as a class to show how to use the information provided to help in the decision making.
    a. Our scenario: You have a farm in Arizona that is growing cherry tomatoes. You are thinking about adding solar panels to your fields. Based on the information given, do you think you should install solar panels?
2. Slied 9: Before evaluating the information, explain that students need to establish the farm's criteria for success. This will help them decide whether to add solar panels. If our success is negatively affected, then solar panels may not be a good choice. On this farm, they need to continue to grow healthy tomatoes and make a profit from those tomatoes. They also need to ensure that the solar panels don't negatively impact them, their farm help, or their community. Tell students that they need to think about how adding solar panels might affect these criteria.
3. Slide 10: Hand out the Arizona farm scenario sheet. Review the information about the farm location as a class. Remind students that local climates, communities, laws, and policies may impact their decision.
4. Ask prompting questions to help students think through how the information might affect their decision. For example:
    a. Does it seem like we have a lot of neighbors? Does this seem like an urban or rural setting? Are there major cities nearby?
    b. What is the main energy source currently for our state? Could solar panels impact the amount of renewable energy in our state? Would it affect the other energy industries in any way?
    c. How friendly is our state to the idea of solar energy? For this state:
        - We can sell energy back to the grid, but the energy companies won't pay us the full value for the energy we produce.
        - In Arizona, there is no tax on purchasing or owning solar panels.
        - There are some local policies supporting solar energy production, but not very many.
        - You receive a credit for installation, but would $1,000 make a big difference relative to the cost of solar panels?
    d. What kind of climate do we live in? Is it hot or cold in the seasons we might be growing crops? Do we get a lot of rain?
    e. Do we get a lot of sun during the day or not? This would impact how much energy solar panels might produce for us.
5. Slide 11: Turn the page over and look at the information about the farm as a class. Ask more prompting questions to help students connect this information to the other side. For example:
    a. What's our annual income? Do we seem to be making a good profit or just getting by?
    b. What kind of climate do tomatoes need? Do they like a lot of sun? Do they need more water than our current climate gets? Would our irrigation system get in the way of the solar panels?
    c. What kind of care and farm tools do we need to maintain our crops? Would any of those tools or care needs be difficult around solar panels? Could they damage the solar panels?
    d. Do our plants grow big? Would we need to put our solar panels on tall stands or short ones? Would that cost more money for install? Would it make solar panel upkeep more difficult?

6. Slide 12: Introduce the poster.
    a. Remind students that they still have criteria for success that they need to meet. If there's more harm than benefits to their crops, their profit, or the people around them, then adding solar panels may not be a good idea for their farm.
    b. Ask students to come up with pros and cons based off the information they just read.
    c. As students give ideas, hand them a sticky note to write their ideas on and add it to the class poster. Take a handful of answers before moving on. There does not need to be an answer for every section. It's better if there are more positives or more negatives. If there is a pattern to their responses, share that pattern with students.
    d. *Note*: All scenarios have a potential answers sheet with ideas of possible pros and cons that students might give.

Group Work (~20 minutes)

1. Slide 13: After going through several pros and cons, ask students if they would add solar panels to their tomato farm in Arizona. Ask what information they used to justify their decision. It might benefit a tomato farm in Arizona, but would it work on a different farm or ranch?
2. Slide 14: Split the class into pairs and have them return their Arizona scenario sheet and pick up a new state scenario sheet and a worksheet.
    a. Instruct them to look over the information on the scenario with their partner and discuss the pros and cons.
    b. Challenge students to try to find at least one pro and one con for each section (product, economics, people). They may have many pros or cons for some sections.
    c. As they discuss their ideas, have them fill out Questions 1-3 on the worksheet.
3. Slide 15: Give each group 2 sticky notes. Make sure those groups who have the same scenario have the same color of sticky notes.
    a. Ask students to write their two strongest arguments on the sticky notes and place them in the correct location on the poster. They can be two pros, two cons, or one of each, but they need to be their strongest arguments.

Discussion (~8 minutes)

1. Using the poster with sticky notes attached, talk about any patterns your students notice. Make sure the contributors of the sticky notes being discussed are sharing what scenario they had and why they felt it was a pro or con.
    a. There may be patterns in the different colored sticky notes and where they are on the poster. Groups that have the same scenario may all find more pros or more cons.
    b. Some submissions may be similar. These could be discussed at the same time.
    c. Some ideas may be contradictory. The opposing contributors could talk through their reasons.
2. Highlight for students that while many plants and animals have similar general needs, they also have unique needs, and we may not know if agrivoltaics will succeed for every crop or on every ranch until we begin to test it. That's why it's being studied.
3. Slide 16: After the discussion, have students turn their worksheet over and choose whether they would add solar panels to their farm/ranch. When explaining their answer, they should include the pros or cons that persuaded them. If they are undecided, have students explain what information they would want before making the decision.

Possible Extensions

- If all three agrivoltaics lessons will be used, leave up the pros and cons poster from this lesson.
    - During the "Made in the Shade" lesson, discuss the sticky notes that may be relevant to their new understanding of photosynthesis and transpiration in plants.

    - After completing the "Solar Energy" lesson, ask students to reevaluate their Farm/Ranch Scenarios. Have students think about the energy efficiency of solar panels that are installed above or near crops or livestock.
- Share with students the agrivoltaics research currently being done throughout the country (see background section and this map that shows research being done throughout the US: https://openei.org/wiki/InSPIRE/Agrivoltaics_Map). In groups, students can explore these projects, learn more, and share with the class what they've learned.

Additional Resources

Barron-Gafford, G. A., Pavao-Zuckerman, M. A., Minor, R. L., Sutter, L. F., Barnett-Moreno, I., Blackett, D. T., Thompson, M., Dimond, K., Gerlak, A. K., Nabhan, G. P., Macknick, J. E. (2019): Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands . *Nature Sustainability 2: 848-855*.

Department of Energy. (2022, June 21). *Buzzing around solar: Pollinator habitat under solar arrays*. Energy.gov. https://www.energy.gov/eere/solar/articles/buzzing-around-solar-pollinator-habitat-under-solar-arrays

Gould, M. C. (2024, September 25). *Agrivoltaic opportunities: Grazing livestock in Solar Energy Systems*. Agricultural Bioenergy and Energy Conservation. https://www.canr.msu.edu/news/agrivoltaic-opportunities-grazing-livestock-in-solar-energy-systems

Gross, S. (2020, January). *Renewables, land use, and local opposition in the United States.* The Brookings Institution. https://www.brookings.edu/wp-content/uploads/2020/01/FP_20200113_renewables_land_use_local_opposition_gross.pdf

Kerber, B. (2025, January 27). *Case study: Pollinator-friendly solar in plains, Georgia*. Fresh Energy. https://fresh-energy.org/pollinator-friendly-solar-in-plains-georgia

National Renewable Energy Laboratory. (2025). *Inspire/agrivoltaics map*. InSPIRE/Agrivoltaics Map | Open Energy Information. https://openei.org/wiki/InSPIRE/Agrivoltaics_Map

University of Minnesota. (n.d.). *Agrivoltaics to Shade Cows*. Agrivoltaics to Shade Cows | West Central Research and Outreach Center. https://wcroc.cfans.umn.edu/research/dairy/agrivoltaics

Arizona Farm Scenario Citations

Bureau, U. C. (2025, January 8). *Data.* Census.gov. https://www.census.gov/data.html

Coolong, T., & Westerfield, R. R. (2015, September 1). *Commercial Tomato Production Handbook*. University of Georgia Extension. https://extension.uga.edu/publications/detail.html?number=B1312&title=commercial-tomato-production-handbook

CNET. (2025). *How solar-friendly is your state? we scored them all.* Ziff Davis Company. https://www.cnet.com/home/energy-and-utilities/how-solar-friendly-is-your-state-we-scored-them-all/

Current Results. (2025). *Average annual Sunshine by State.* Current Results Publishing Ltd. https://www.currentresults.com/Weather/US/average-annual-state-sunshine.php

Southwest Climate Hub. (n.d.). *Tools.* Climate Hubs U.S. Department of Agriculture. https://swclimatehub.info/decision-support/tools/

United States - Energy Information Administration (EIA). (2022). *U.S. States Total Energy Production and consumption by state, 2022.* U.S. Energy Information Administration - EIA - independent statistics and analysis. https://www.eia.gov/beta/states/overview

California Farm Scenario Citations

Almond Board of California. (2024). *Almonds Lifecycle I Ideal Mediterranean Climate.* https://www.almonds.com/why-almonds/growing-good/almond-lifecycle

Anderson, M. (n.d.). *Almond growing guide.* Anderson's Seed & Garden. https://andersonseedandgarden.com/blogs/knowledge-center-plants-growing/almond-growing-guide
Bureau, U. C. (2025, January 8). *Data.* Census.gov. https://www.census.gov/data.html
CNET. (2025). *How solar-friendly is your state? we scored them all.* Ziff Davis Company. https://www.cnet.com/home/energy-and-utilities/how-solar-friendly-is-your-state-we-scored-them-all/
Current Results. (2025). *Average annual Sunshine by State.* Current Results Publishing Ltd. https://www.currentresults.com/Weather/US/average-annual-state-sunshine.php
Southwest Climate Hub. (n.d.). *Tools.* Climate Hubs U.S. Department of Agriculture. https://swclimatehub.info/decision-support/tools/
United States - Energy Information Administration (EIA). (2022). *U.S. States Total Energy Production and consumption by state, 2022.* U.S. Energy Information Administration - EIA - independent statistics and analysis. https://www.eia.gov/beta/states/overview

Nevada Farm Scenario Citations

Bureau, U. C. (2025, January 8). *Data.* Census.gov. https://www.census.gov/data.html
CNET. (2025). *How solar-friendly is your state? we scored them all.* Ziff Davis Company. https://www.cnet.com/home/energy-and-utilities/how-solar-friendly-is-your-state-we-scored-them-all/
Current Results. (2025). *Average annual Sunshine by State.* Current Results Publishing Ltd. https://www.currentresults.com/Weather/US/average-annual-state-sunshine.php
Southwest Climate Hub. (n.d.). *Tools.* Climate Hubs U.S. Department of Agriculture. https://swclimatehub.info/decision-support/tools/
United States - Energy Information Administration (EIA). (2022). *U.S. States Total Energy Production and consumption by state, 2022.* U.S. Energy Information Administration - EIA - independent statistics and analysis. https://www.eia.gov/beta/states/overview
Utah State University (2024, February 29). *How to grow potatoes in your garden.* USU Extension. https://extension.usu.edu/yardandgarden/research/potatoes-in-the-garden#
Yankee Publishing. (2025, February 6). *How to grow potatoes: The complete guide*. Almanac.com. https://www.almanac.com/plant/potatoes

New Mexico Farm Scenario Citations

Bureau, U. C. (2025, January 8). *Data.* Census.gov. https://www.census.gov/data.html
CNET. (2025). *How solar-friendly is your state? we scored them all.* Ziff Davis Company. https://www.cnet.com/home/energy-and-utilities/how-solar-friendly-is-your-state-we-scored-them-all/
Current Results. (2025). *Average annual Sunshine by State.* Current Results Publishing Ltd. https://www.currentresults.com/Weather/US/average-annual-state-sunshine.php
Navajo-Churro Sheep Association. (2025, February 24). *America's first sheep.* N-CSA. https://www.navajo-churrosheep.com/
Southwest Climate Hub. (n.d.). *Tools.* Climate Hubs U.S. Department of Agriculture. https://swclimatehub.info/decision-support/tools/
United States - Energy Information Administration (EIA). (2022). *U.S. States Total Energy Production and consumption by state, 2022.* U.S. Energy Information Administration - EIA - independent statistics and analysis. https://www.eia.gov/beta/states/overview