Mining 5E

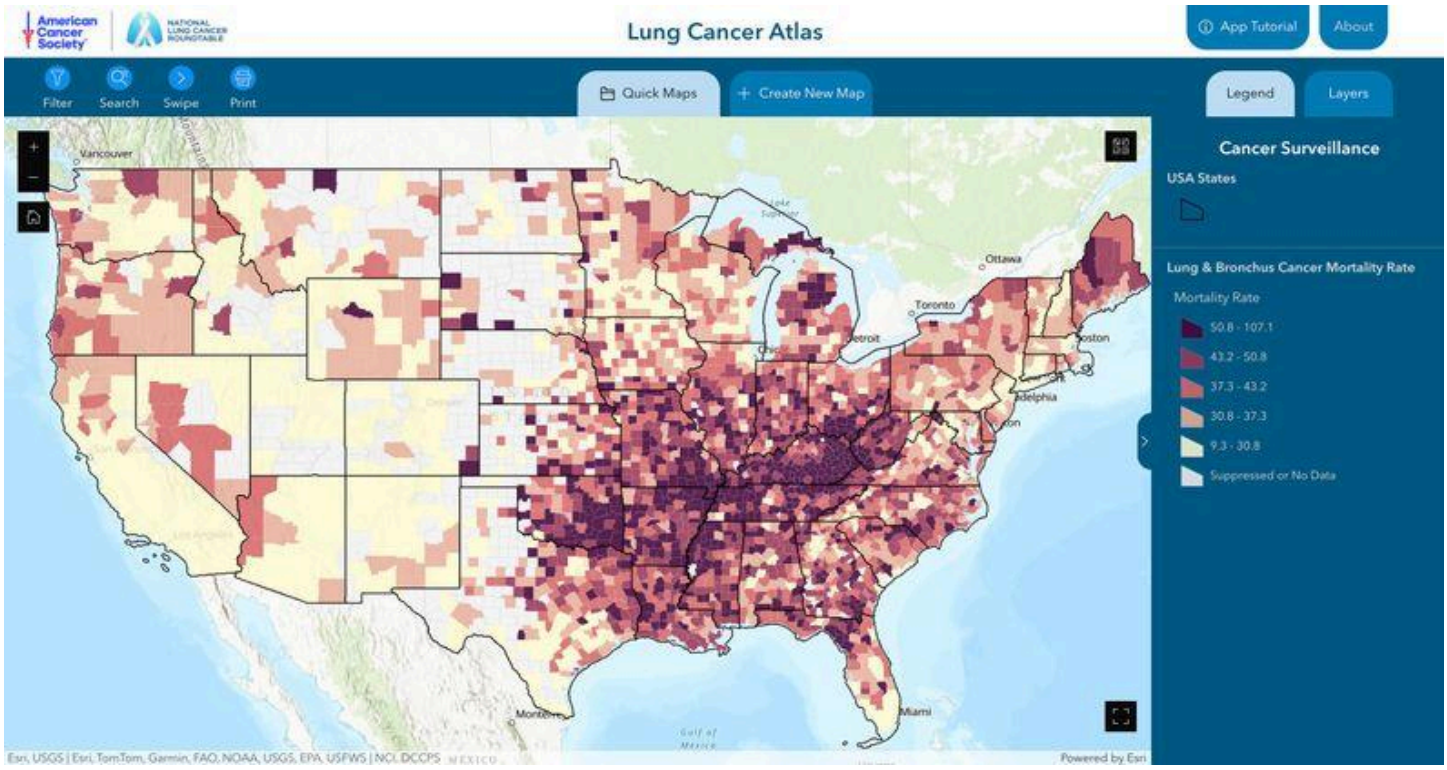
Unit 6 Solutions for a Sustainable Future	Earth and Space Science
Student Name:	

Cancer and Biodiversity Loss in the United States

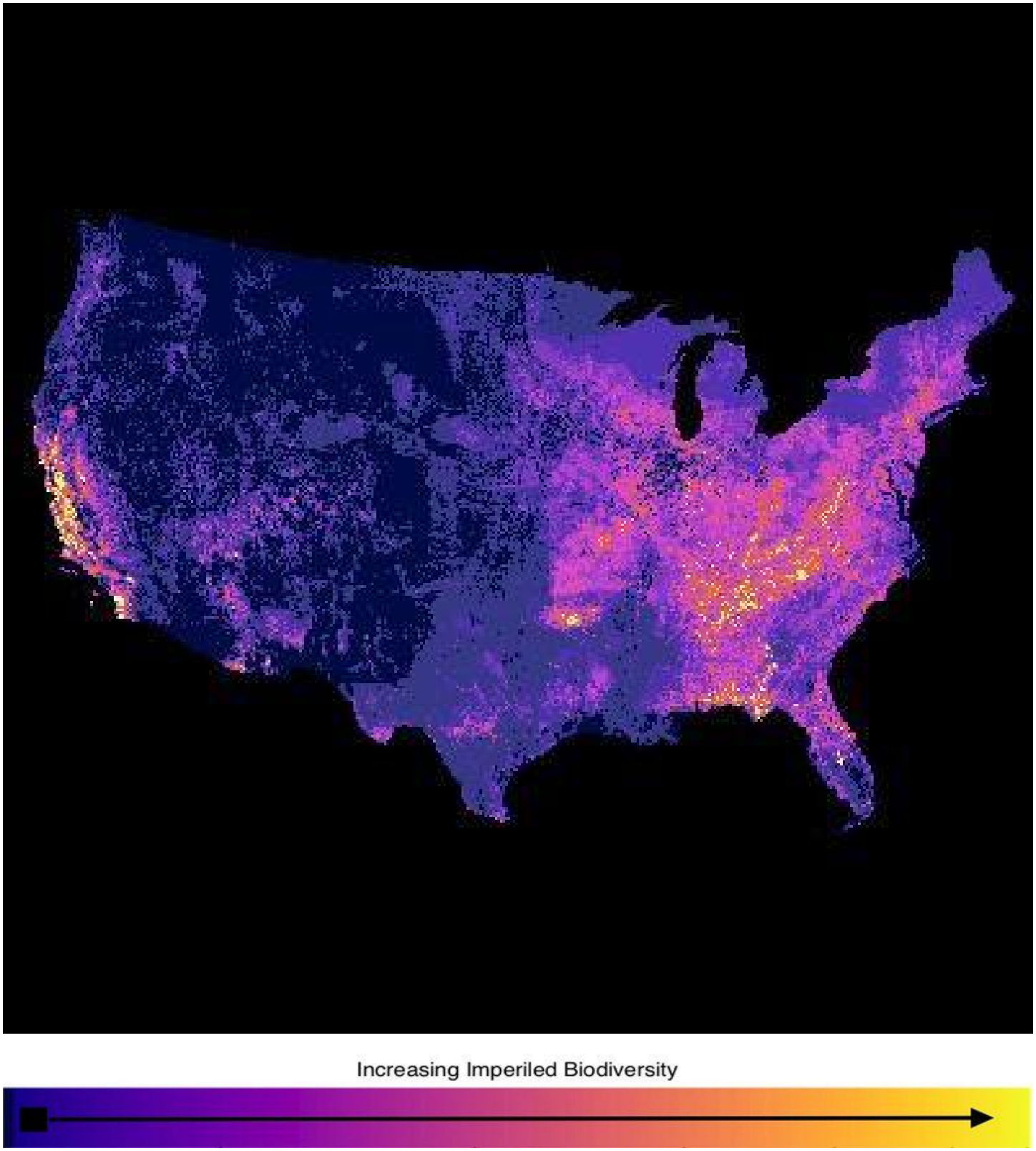
One of the diseases that can be caused by environmental causes and kills many people worldwide is cancer. In the United States, cancer diagnoses are not evenly distributed, which may be related to varied environmental conditions.

Directions: Analyze the maps below and write down your observations, what they make you think about, and any questions you have in the See-Think-Wonder chart below.

American Cancer Society Lung Cancer Atlas



Map of Imperiled Biodiversity in the United States


Increasing Imperiled Biodiversity

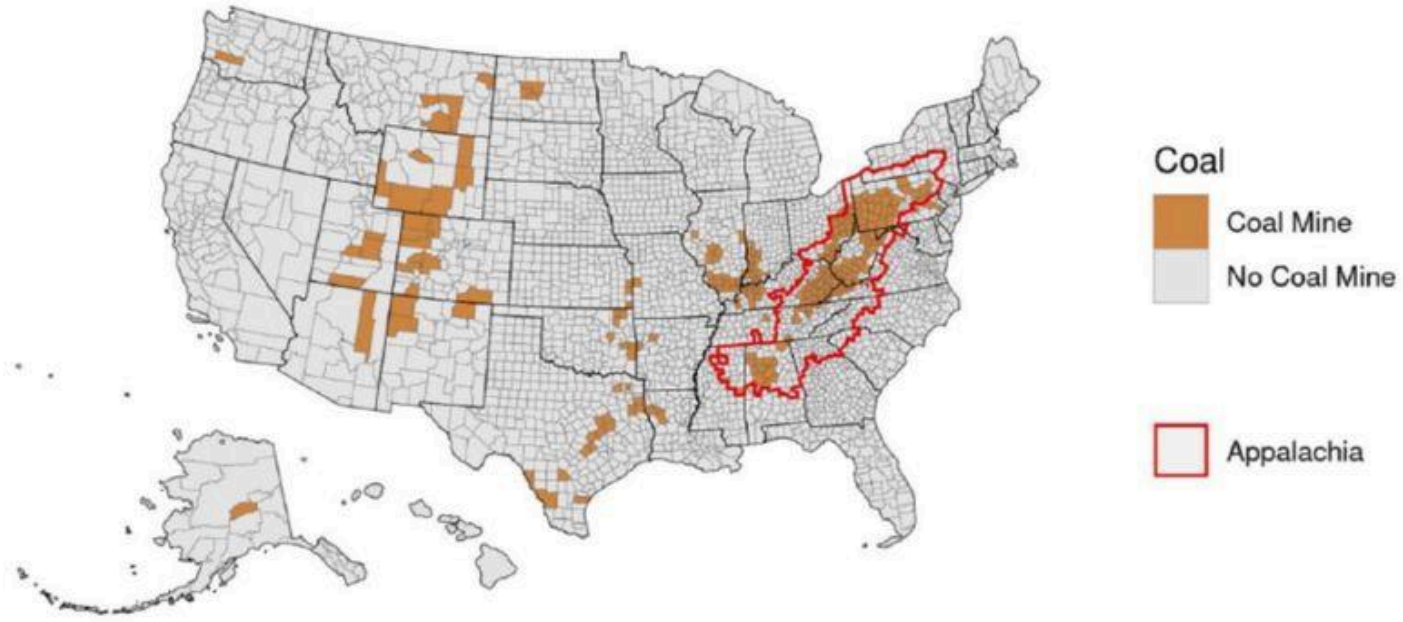
See-Think-Wonder

Use the graphic organizer below to record your ideas.

See What did you observe in the video and the graph?	**Think** What do those observations make you think about?	**Wonder** What questions do you have?
What patterns do you notice about the distribution of lung disease?		
What patterns do you notice about the distribution of at-risk biodiversity?		

Extracting Materials from the Earth

Introduction: Coal is a fossil fuel burned to generate electricity and used in industrial processes. It is found underground and must be extracted from the earth through mining. Mining is concentrated in two areas in the United States as shown below.



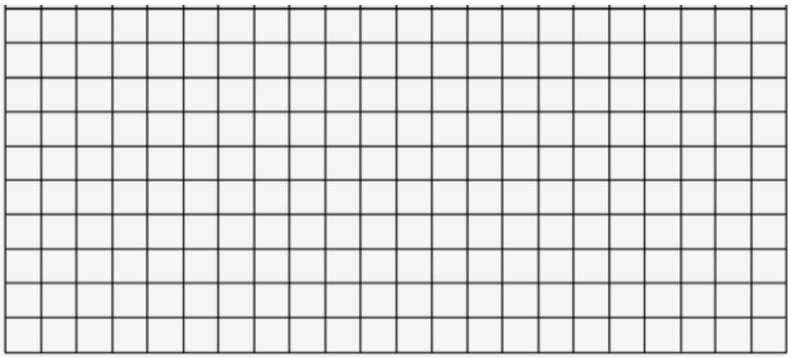
Predict: How do you think mining for resources impacts the environment around mines?

Procedure

Part 1: Extraction of ores from the Earth

Mine owners and investors face many challenges in the successful operation of any mine, where it may be extremely difficult to turn a profit. Obtaining the land, labor, equipment, safety, and reclamation are the chief concerns of the owner. To understand some of these challenges, you will attempt to conduct a rare Earth element mining business in an experiment that requires you to mine the ore (chocolate chips) from a plot of land (cookies). The equipment for your mining will be a paperclip that you may modify in any fashion.

1. Measure the mass of the cookie holder and the processing plant, and record it above Table 1.
2. Measure the mass of the complete cookie and record it in Table 1 in the first row.
3. Looking from the side of the cookie, sketch the shape of the "landscape" (the shape of the side view)



4. Place your cookie in the mining container provided by your teacher.

5. Choose a spot to put your cookie in its container on the Mining Area Grid and trace around the edge of the container.

6. Next to your cookie, place the “processing plant” provided by your teacher. Trace the outline of this processing plant.

7. **Extracting the Ore:** Set a 5 minute timer for the ore extraction. Extract the ore from the cookie by removing as many chocolate chips as possible from the cookie and relocating them to the processing plant using only your toothpicks or paper clips.

Rules for extraction of ore
The cookie must stay flat on the grid at all times. You may use your fingers to hold it stably in place.
Only mining tools (paperclips or toothpicks) may be used to extract chocolate chips from the cookie.
Calculating Contamination: Determine the masses of the cookie, the chocolate chips in the processing plant (including any pieces of cookie that are stuck), and any stray crumbs and record them in the second row of Table 1. Follow the steps below:

- Measure the mass of chocolate chips and any crumbs that are in your processing plant by lifting the processing plant container off the paper and onto the scale.
- Measure the mass of the remaining cookie by lifting the cookie container off the paper and moving it onto the scale.
- Subtract the remaining cookie’s mass and the mass of chocolate chips and crumbs in the processing plant from the original cookie’s mass to calculate the mass of any stray crumbs that may have gotten lost or landed on another part of the grid.
- Replace the cookie in its container and the processing plant to their original locations marked on your paper.

8. **Reclamation of the Land:** Set a 5 minute timer, then process the ore and attempt to reclaim your land by using your mining tools to clean the chocolate chips by removing any remaining cookie and return all crumbs from the processing plant back within the original circle of your mining operation.

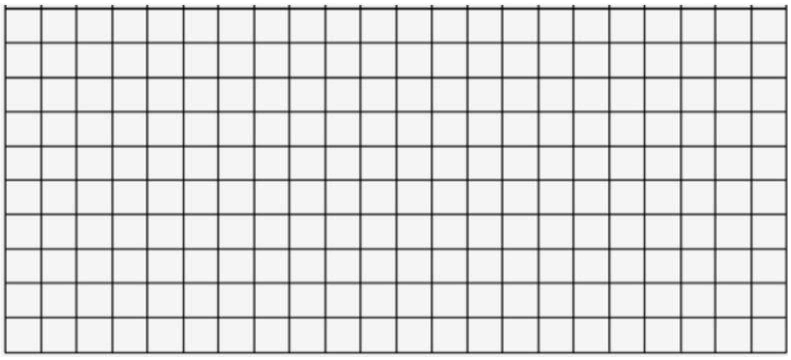
Rules for reclamation (taking back the land) and ore processing
All mined ore (chocolate chips) must be cleaned and transported to the processing plant on your paper.

9. **Calculating Land not Reclaimed:** After the reclamation time is up, determine the final masses of each item in Table 1 and record the measurements in the third row of that data table.
    - Measure the mass of the processed (clean) chocolate chips by using the mining tools to remove the clean chips from the processing plant and move them into a new container on the scale.
    - Measure the mass of any remaining crumbs and uncleaned chocolate chips in the processing plant by lifting the processing plant off the paper and moving it onto the scale (ideally, this is 0)
    - Measure the mass of the cookie remaining in the original mining area by lifting the cookie container off the paper and moving it onto the scale.
    - Use those three numbers to calculate the stray crumbs that did not get reclaimed.

Part 2: Evaluating impacts from extraction of ores from the Earth

When mining is complete, the mining companies have the benefit of the economic impact (money) from whatever they mined. However, there are also impacts to the environment that have to be considered. In this part, we will try to quantify the environmental effects from mining.

1. Looking from the side, sketch the topography (the natural physical features of the land) on the "Post-Mining Topography (*side view*)" graph below to show the ridges and valleys of the land.



Now, we will count how much of each natural feature was impacted directly by the mine or processing plant, indirectly, or remained healthy at the end. Work with your partner to determine the numbers of affected and healthy squares of each resource by following the steps below.

2. Lightly shade in all the boxes containing the mine or processing plant.

3. Count how many grid squares contain cookie/crumbs/smudges the mining operation left behind. Even the *tiniest* speck counts! Draw an X through each of those boxes.

4. The water flows from the top left of the grid to the bottom right, following the branches as it goes down. Find all the water downstream from any shaded box or box with an X, and draw Xs through those boxes. This water is all contaminated by acid runoff from the mining process.

5. Each topsoil square not shaded brown or within the mining or processing areas may still be healthy, but each square needs two clean water squares to keep its moisture. Divide your clean water by two to determine how many rich topsoil squares have remained clean, and draw an X through all the remaining topsoil boxes.

Clean water squares _____ = number of remaining topsoil squares 2

6. One clean rich topsoil will support three trees. Take the number of rich topsoil boxes remaining and multiply it by three to determine how many trees can be supported. Draw an X through the other tree boxes.

Clean topsoil squares x 3 = number of remaining tree squares

7. Each deer requires three trees and three water. Using the number of healthy remaining water and trees, determine how many deer remain. Draw an X through the other deer boxes.

Clean tree squares _____ = possible number of remaining deer squares 3 Clean water squares _____ = possible number of remaining deer squares 3 Select whichever number is smaller

8. Scenic vistas cannot have any damaged (shaded or crossed off) boxes touching them on any side or corner. Draw an X through any shaded vistas in contact with an impacted box.

9. Count the number of boxes containing each resource in the mining or processing areas (shaded squares). These are the resources directly impacted by mining and processing. Record these numbers in the first column of Table 2.

10. Count the number of boxes containing each resource that were indirectly affected by mining (squares with Xs). Record these numbers in the second column of Table 2.

11. Count the number of boxes of each resource remaining healthy (no shading or Xs). Record these numbers in the third column of Table 2.

12. Once your land and ore have been assessed you may eat your cookie.

Data Tables

Mass of empty cookie holder:

Mass of empty processing plant:

Table 1: Ore at Mining Location				
	Cookie	**Chocolate Chips**	**Crumbs in Processing Plant**	**Stray Crumbs**
Before Mining		**0**	**0**	**0**
After Mining, Before Reclamation		*These numbers are combined at this point:*		
After Mining and Reclamation				

Table 2: Environmental Impacts			
Natural Attribute	**Quantity Directly Impacted by Mine or Processing Plant Location**	**Quantity Indirectly Impacted by Mining & Processing**	**Remaining Healthy Attributes After Mining and Reclamation**
Tree (33)			
Deer Habitat (10)			
Rich Topsoil (12)			
Water (41)			
Beautiful Vista (9)			

Analysis of the mining impact

1. Using *Table 1. Ore at Mining Location*, calculate the benefit of mining ore.
    - Each gram of chocolate is 100 tons of coal
    - Each ton of coal generates $50
    - Each ton of coal provides 2000 kilowatt hours of electricity, costing about $350 - about 1 month of electricity for one household
    - Each ton of coal employs 1 person for 15 minutes, earning them about $5

1. Calculate the number of tons of coal: weighed mass x 100 = number of tons of coal
   Your work here:

2. Calculate the financial benefit:
   Financial Benefit = (money earned) + (months of electricity gained) + (salary paid)

   Financial Benefit = (number of tons x $50) + (number of tons x $350) + (number of tons x $5)

   Your work here:

2. Using *Table 2. Environmental Impacts*, determine a way to calculate the impact mining had on the environment.

1. Calculate the percent of each resource lost to mining

Percent lost = (number of lost squares/number of original squares) x 100
Your work here:

Tree:

Deer Habitat:

Rich Topsoil:

Water:

Beautiful vista:

2. Calculate the amount of unrecovered land (lost cookie crumbs)

Percent lost = (stray crumbs/original cookie mass) x 100
Your work here:

3. Calculate the environmental impact on the area

Environmental Impact = Lost Trees + Lost Deer + Lost topsoil + Lost water + lost vistas + unrecovered land
Your work here:

3. Compare your environmental impact scores with those of your tablemates. How did their different approaches (placement of the mine and method of removal) affect their scores compared to yours?

Analysis questions - answer the following in complete sentences.

1. Were you able to restore the mined cookie to exactly its original size and topography? Explain why or why not.

2. How easy was it to refine your ore so you had clean chocolate chips? Were you successful at refining the chocolate without impacting other areas of the grid?

3. Based on what you experienced in this activity, how do you think mining and refining processes impact ecosystems?

4. The benefits of mining were calculated as financial benefit (in dollars), which is earned by mining companies, electricity companies, and wage earning mining staff. The costs of mining were measured as natural features that were lost (not in dollars).

Why do you think we did not measure the loss of natural resources in dollars?

5. If mining companies were responsible for paying for the environmental costs of their work, energy from coal would likely become more expensive.

    a. Would this be a good or bad thing? Explain.

    b. How do you think an increase in the price of coal-generated energy would affect the demand for coal?

    c. How do you think an increase in the price of coal-generated energy would impact the demand for other energy sources?

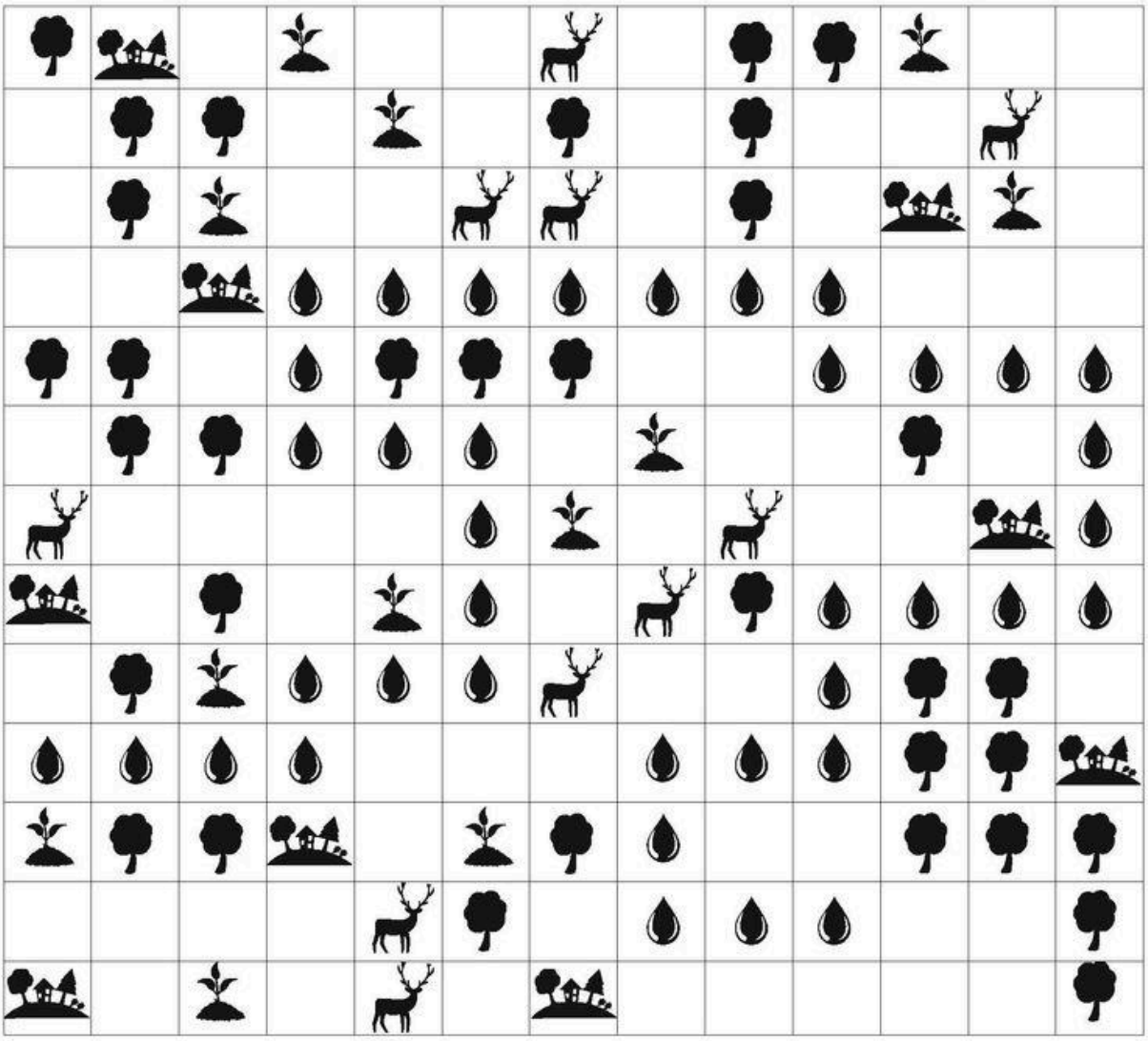
See-Think-Wonder

Directions: Refer to the mining investigation to complete this chart.

See What pattern did you observe in the data?	Think What could this pattern mean?	Wonder What questions do you have about this pattern?
What did you notice about the ease or difficulty of getting the ore?		
What did you notice about the ways coal benefits the economy?		
What did you notice about the impacts mining had on the land and natural resources?	How do you think the use of coal would be changed if companies had to consider the environmental costs?	

Mining Area Grid

MINING AREA GRID



Natural Attributes:

Tree

Deer habitat

Rich top soil

Water

Beautiful vista

Costs and Benefits of Mountaintop Removal Coal Mining

In this activity, you will apply what you learned in the explore phase to human health. First you will brainstorm how the environmental impacts of mining might cause human death. Then you will read about the known impacts of coal mining on environmental and human health to fully define the problem in need of solving.

Based on what you observed in the explore phase, describe the costs and benefits of mining. How do you think our ability to use technology like mountaintop removal mining to extract useful resources impacts human health?

Benefits	Costs

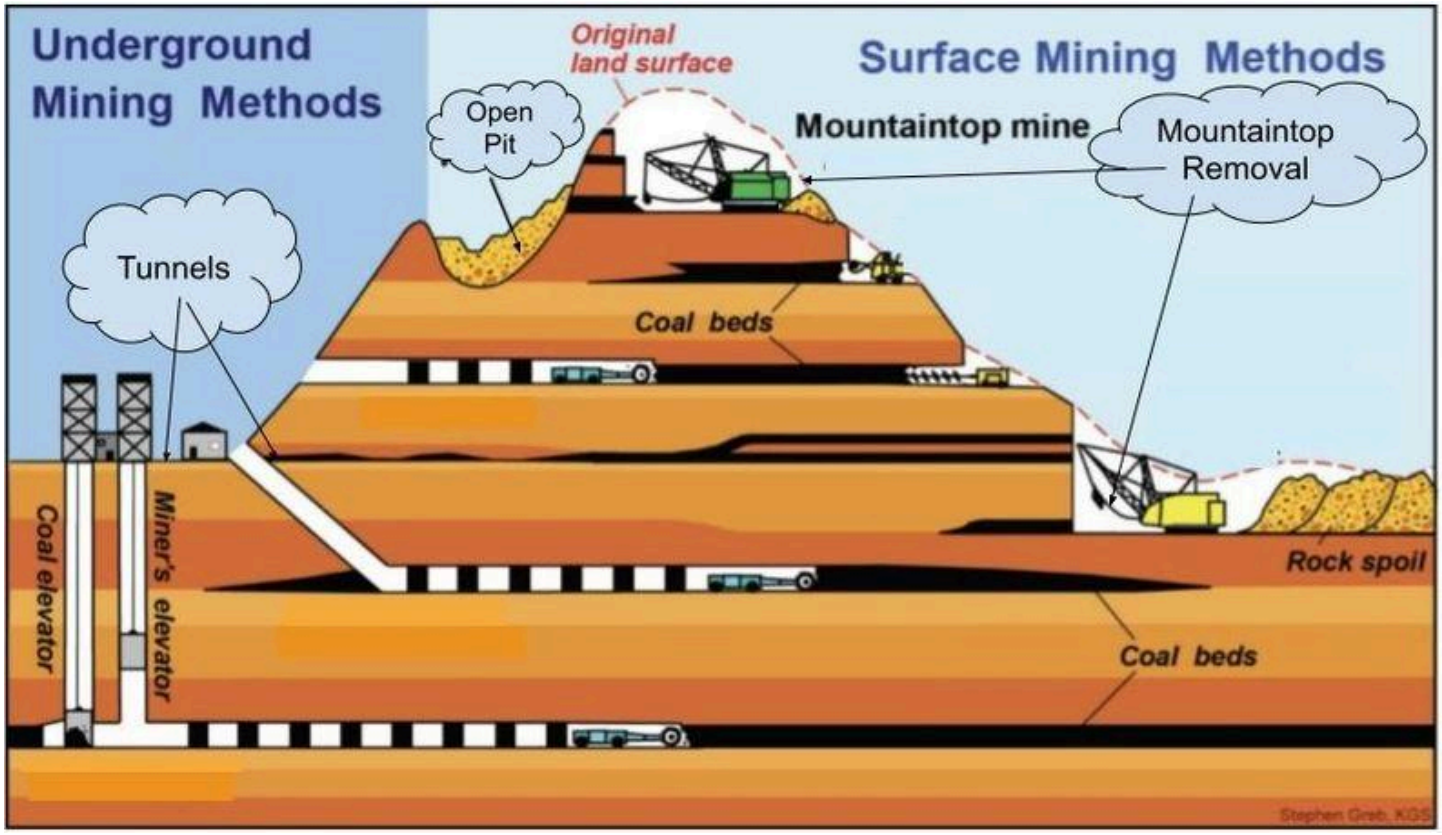
Introduction: Read and annotate the text
While you read the text, annotate it by:

- Putting (+) next to benefits of coal mining
- Putting (-) next to costs of coal mining

Coal is a fossil fuel used to generate electricity in power plants and in industrial processes like making steel and cement. Some historians have argued that the industrial revolution couldn't have happened without coal to power steam engines and refine the steel used for building bridges and railroads. However, obtaining coal is costly. Mining it requires digging into rocks to extract coal from the ground, separating out the valuable coal from the waste rock. In some places, like Wyoming, the coal is near the surface and can be mined by removing all the plants and soil from the area, extracting the coal, and filling the pit back in with soil and replanting.

In other places, like the Appalachian mountains across Kentucky and West Virginia, the coal is buried deep underground and within mountains, which makes it very hard to access. Historically, tunnels were carved into the mountains to access the deep coal inside, creating very dangerous working conditions for the miners inside.

In present times, coal is extracted from the Appalachian mountains using a technology called mountaintop removal coal mining. In this process, the tops of mountains are blasted off with explosives, revealing the coal underneath. Because this method is so disruptive to the natural environment, it is very difficult, if not impossible, to return these mining sites to the way they were before. While this process is safer for miners, less expensive for mining companies, and more efficient for extracting coal, it comes with costs to ecosystems and people in the surrounding communities.



Read your assigned text and take notes about your ideas and questions in the space below.

Text 1: Mountaintop Removal Coal Mining and the Ecosystem
Text 2: Mountaintop Removal Coal Mining and Human Health

I am reading text #

Notetaker:
How does mountaintop removal coal mining stabilize or destabilize the environment and human health?

Think-Talk-Open Exchange

1. **Think -** Respond to the prompt individually, in the space below.

Developing new technologies, like mountaintop removal mining, creates both benefits and costs to natural and man-made systems. Write a paragraph about the benefits and costs of using mountaintop removal coal mining (societal, economic, environmental, and health), and how it stabilizes and/or destabilizes man-made or natural systems.

Buzzwords: benefit, cost, stabilize / destabilize, resource

2. **Talk**: Share with your group one at a time. Write a tally mark (✔✔✔✔) each time you hear a specific buzzword during the share.

	benefit	cost	stabilize / destabilize	resource
Person 1				
Person 2				
Person 3				

3. **Open Exchange:** As a group, discuss the following questions- be sure to use the buzzwords!

- Describe patterns or commonalities between what each group member shared.
- Which buzzwords did you hear the most? Least?
- Are there buzzwords that your group doesn't understand?
- Are there other words you heard a lot? If so, which words?

4. **Reflection -** Individually respond to the prompt below.

What are some new ideas you heard during your discussion with your group?

Summary Task

Today we completed a class consensus discussion! How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

1. Describe how human actions may both stabilize and destabilize a natural system.

2. Evaluate the use of mountaintop removal to mine coal for energy and industry. Be sure to include a discussion on the use of this technology based on associated economic, environmental, and geopolitical costs, risks, and benefits.

Mining and Mineral Identification in New York State

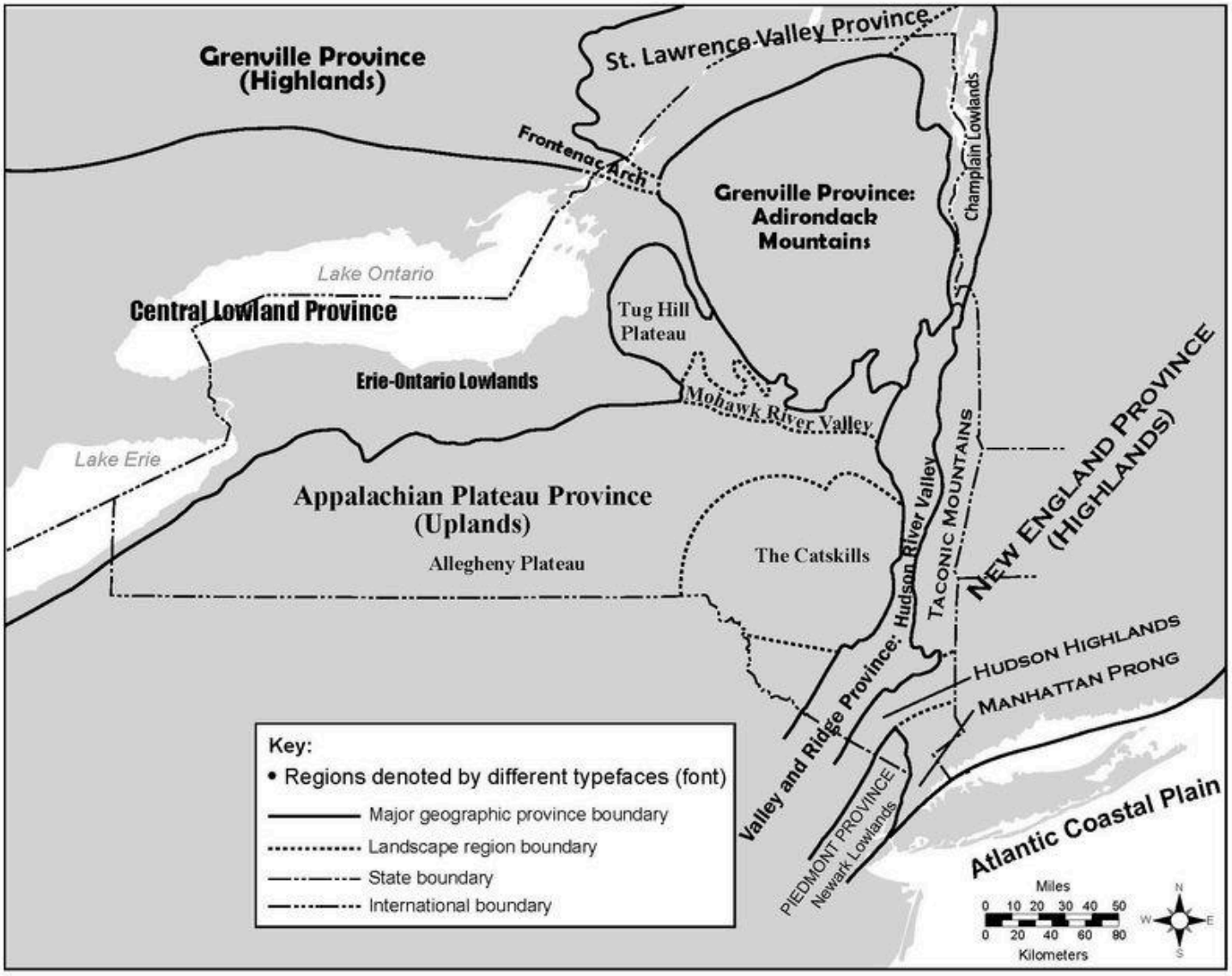
Part 1. What mineral resources are available in New York?

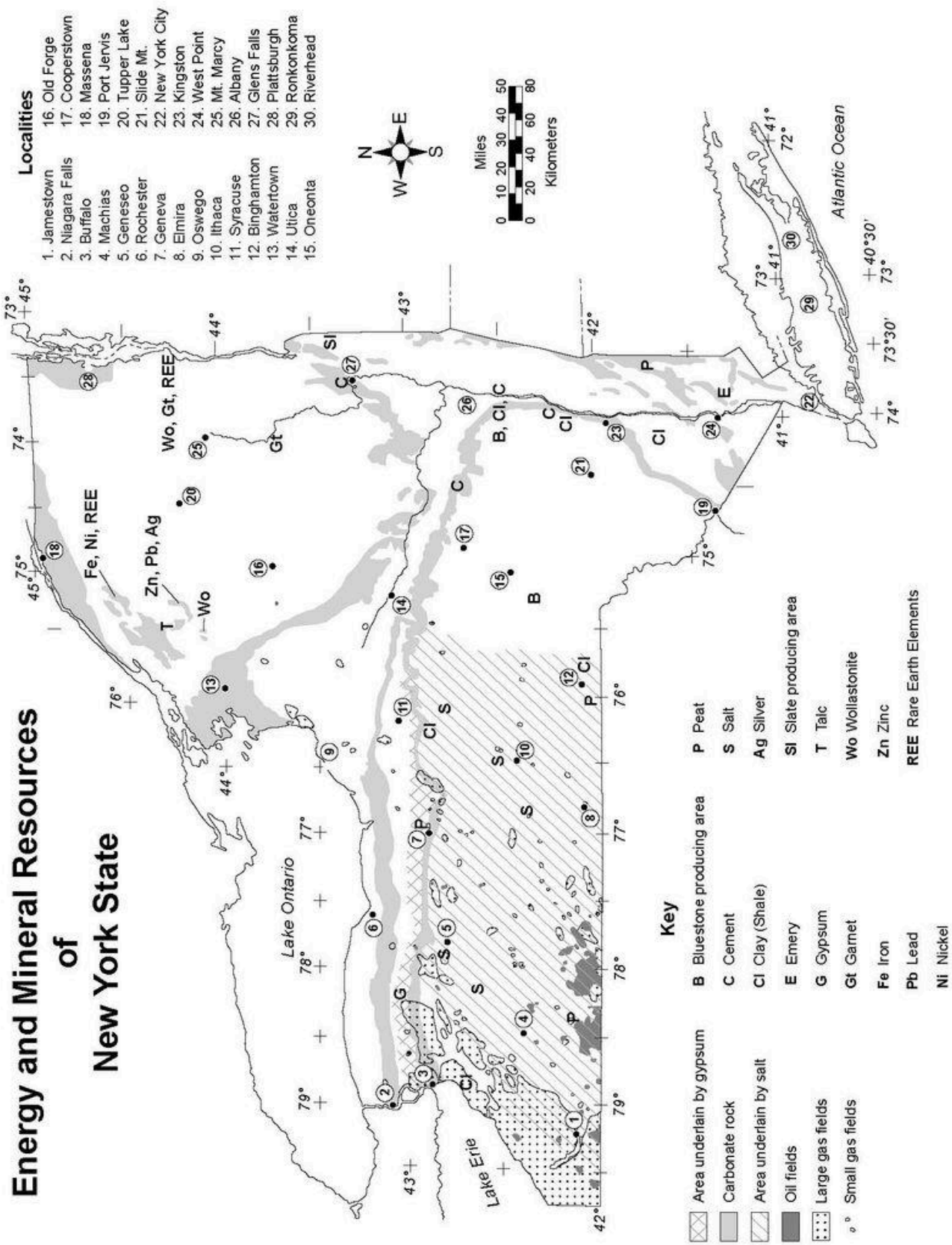
Just north of the Appalachian coal mining region is New York State, which includes the top part of the Appalachian Plateau Province, as seen below. Unlike the rest of Appalachia, however, New York does not have any coal reserves.

Instead, New York has a different set of energy and mineral resources which vary depending on the region within the state.

Use the maps on this page and the next to determine what resources are available in New York and predict how their mining approaches may vary based on where they are located.

GEOGRAPHIC PROVINCE AND LANDSCAPE REGIONS OF NEW YORK STATE





1. What types of energy resources does New York have?

2. What other types of resources does New York have?

3. Based on these maps, which types of resources tend to cluster around water sources or rivers?

4. Based on both maps, which resources tend to cluster in mountains?

5. Using what you learned about the challenges of coal mining in Appalachia versus Wyoming, which resources do you think would be most environmentally damaging to extract?

Part 2. How do we know when we find a valuable mineral?

Scientists use various tests to determine what type of mineral they are looking at. In this investigation, you will analyze samples using different tests and then sort them using the mineral identification chart to determine what minerals you are looking at.

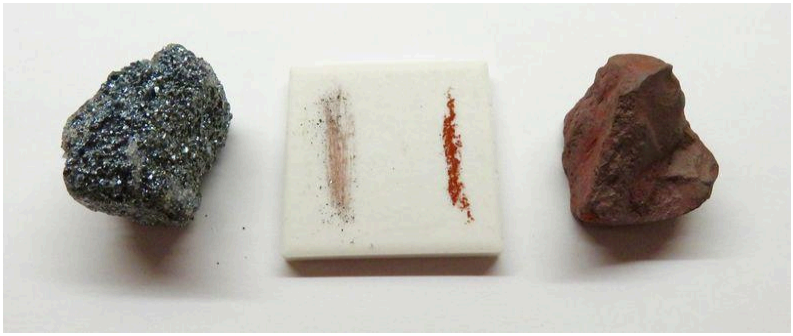
Materials:

- Mineral samples
- Copper penny
- Steel nail
- Glass plate
- Streak plate
- Dilute HCl
- Dropper

Test 1. Metallic or Nonmetallic luster.
Look at the surface of the mineral. If it is opaque (you can't see light through it) and shiny, the mineral is "metallic." If you can see light through it or if it isn't shiny, it is "nonmetallic." Examine each sample and record your observation in Table 1.

Test 2. Hardness: determine the nonmetallic minerals' hardness by following the steps below and recording the results in Table 1.

1. Scratch the mineral with your fingernail. If your fingernail leaves a mark, the mineral has a hardness of less than 2.5.
2. If your fingernail doesn't leave a mark, scratch the mineral with a copper penny. If the copper penny leaves a mark but the fingernail did not, the mineral has a hardness of approximately 3.
3. If the penny doesn't leave a mark, scratch the mineral with a steel nail. If the nail leaves a mark but the penny did not, the mineral has a hardness of approximately 4.
4. If the nail doesn't leave a mark, scratch the mineral with the glass plate. If the glass leaves a mark but the penny did not, the mineral has a hardness of higher than 5.5.

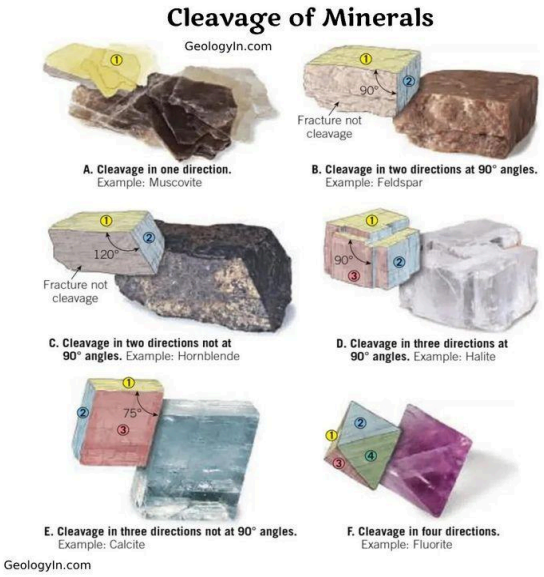


Test 3. Streak Test
Drag each mineral across the streak test plates. Record the color (or lack of color) left behind in Table 1.

Test 4. Rock Cleavage
Cleavage means how a mineral breaks. Minerals with cleavage mean the mineral breaks along flat planes, creating smooth sides in at least one direction. Minerals with no cleavage are rough or irregular shapes.

Minerals with cleavage in one direction have smooth flat surfaces in one direction (two opposite sides parallel to each other); minerals with cleavage in two directions have smooth flat surfaces in two perpendicular directions (four sides of a cube), with rough sides on the remaining direction; minerals with three directions of cleavage are smooth all around. Cleavage in 4 directions will produce a shape that looks like two pyramids put together. These directions of cleavage can be at perfect 90 degree angles or slanted.

Observe the shapes of each mineral sample and record your observations in Table 1. You can use the image to the left or the video link to help you determine if the mineral has cleavage, and if so, in how many directions.



When all four tests are complete, use the Mineral Identification Flowchart below to determine which mineral(s) your sample could be. It is likely that you will not have a final determination for them yet.

Table 1. Mineral Test Results

Sample	Metallic or Nonmetallic	Streak Test	Hardness	Cleavage	Based on the first four tests, what minerals could the sample be?
A					
B					
C					

D					
E					

For each of your samples, complete Table 2 by following these directions:

1. State the information you need in order to determine which of the possible minerals the sample is.
2. Conduct the necessary tests or observations, and record your observations.
3. Determine what mineral each sample is, and support your answer with evidence from your tests and observations.

Additional information that may help you with these tests and observations is listed here:

- For any sample that requires an acid test, place one drop of dilute hydrochloric acid (HCl) on the sample and watch for bubbles to appear. If there are bubbles, it has a positive acid test.

- Types of nonmetallic luster:
    - Vitreous = glassy
    - Earthy/dull = not shiny
    - Resinous = like tree sap

- Pearly = shiny like pearls
- Waxy = like a candle

Table 2. Determining mineral identification

Sample	What additional information would help you determine which mineral you have?	Conduct the test(s) or observation(s). Record your observations in the space below.	What mineral is it? Support your answer with evidence from your tests and observations.
A			
B			
C			
D			
E			

See-Think-Wonder

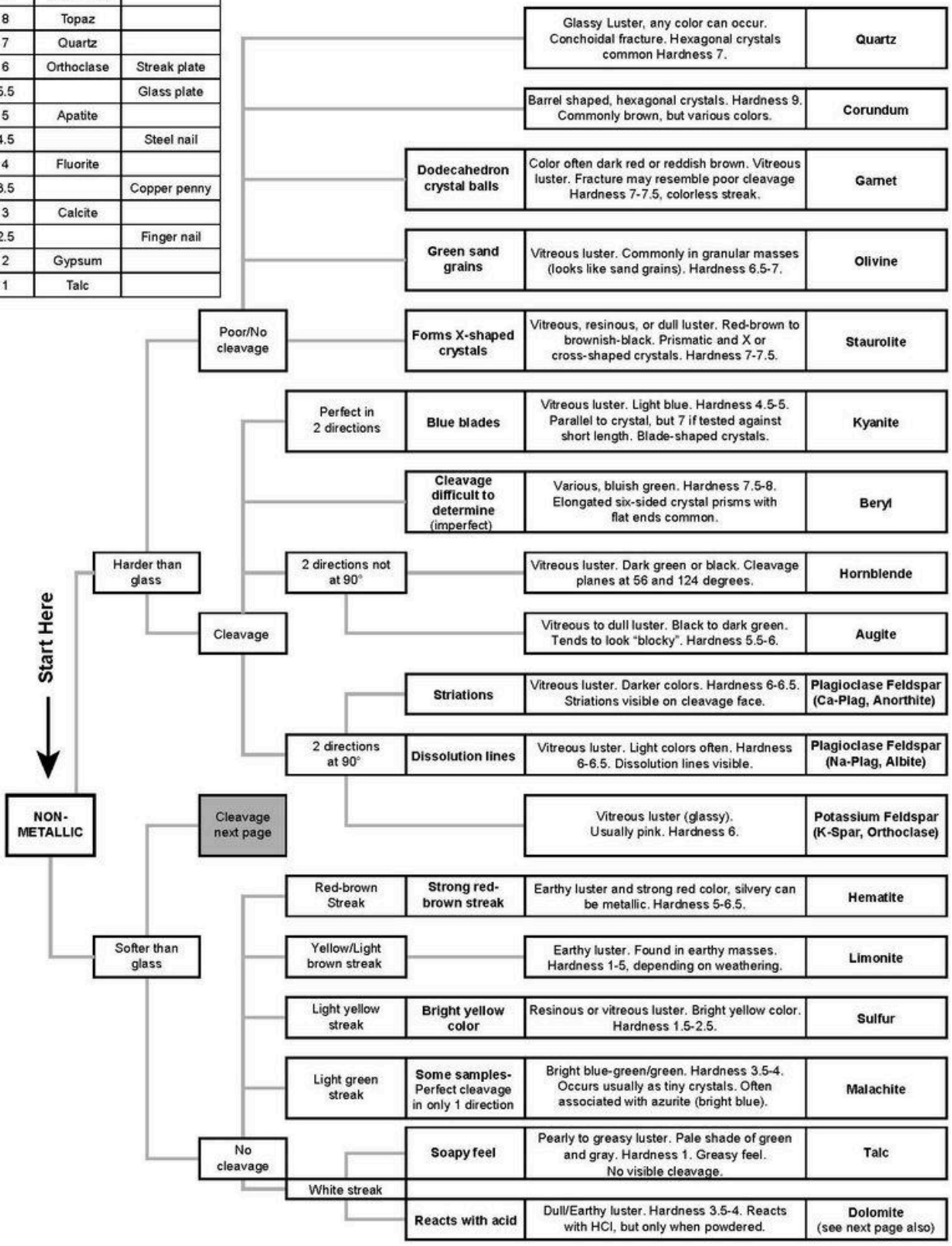
Directions: Refer to the mineral investigation to complete the table below.

See What pattern did you observe in the data?	Think What could this pattern mean?	Wonder What questions do you have about this pattern?
What do you notice about the distribution of energy resources in New York?		
What do you notice about the distribution of mineral energy resources in New York?		
What do you notice about the types of land the minerals are found in?	How do you think geological features might impact the difficulty of extracting the resource? How do you think the difficulty of extracting the resource relates to the damage done to extract the resource?	

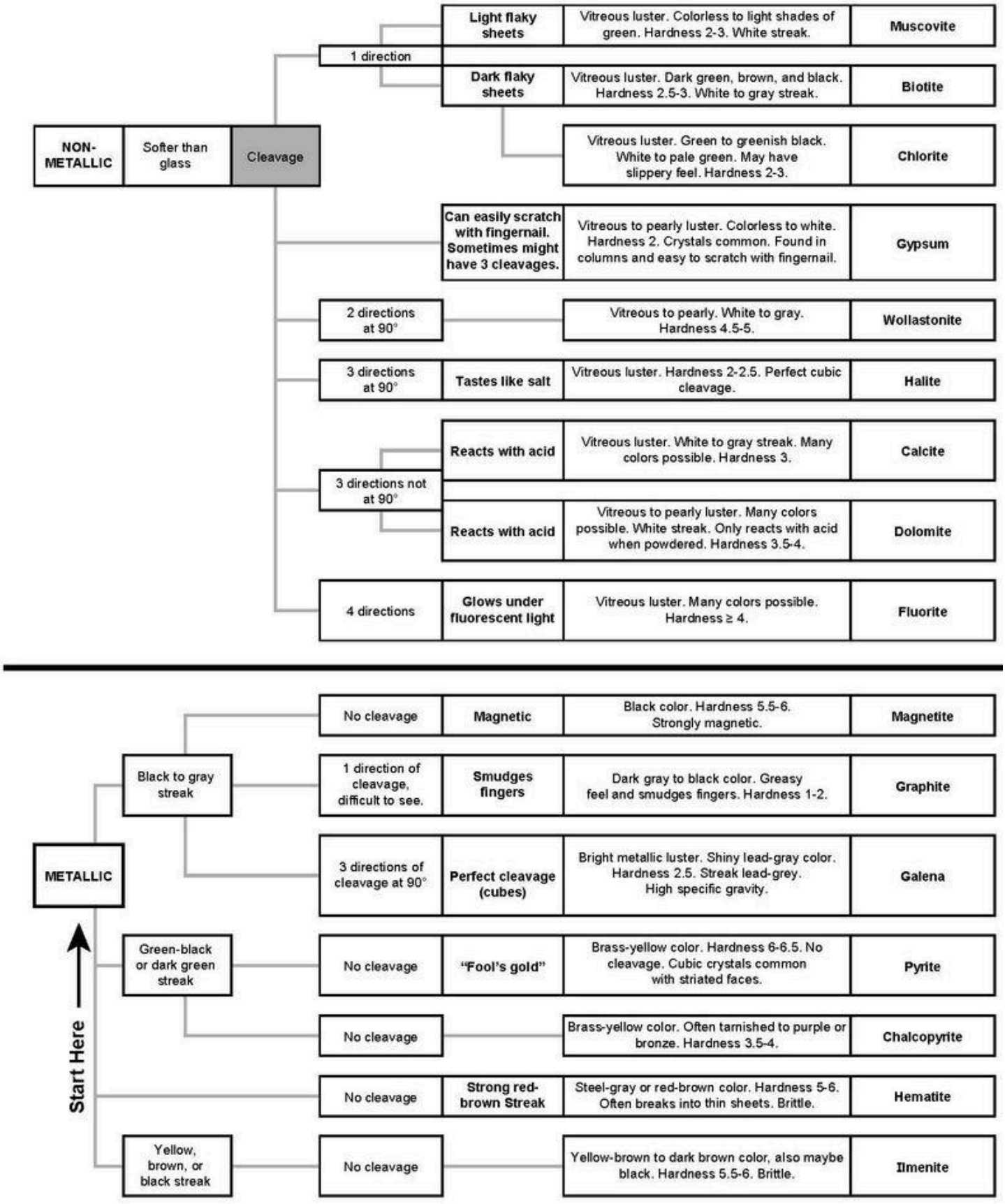
Mohs Hardness Scale

Hardness	Mineral Name	Tools
10	Diamond	
9	Corundum	
8	Topaz	
7	Quartz	
6	Orthoclase	Streak plate
5.5		Glass plate
5	Apatite	
4.5		Steel nail
4	Fluorite	
3.5		Copper penny
3	Calcite	
2.5		Finger nail
2	Gypsum	
1	Talc	

Mineral Identification Flowchart



Mineral Identification Flowchart (Continued)



Summary Task

Today we completed a class consensus discussion! How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

1. How do social and cultural contexts impact the ways solutions are evaluated to inform decisions about mining regulations?

2. In what ways does New York balance competing economic, societal, environmental, and ethical considerations to increase benefits and decrease costs?

Costs and Benefits of Mining in New York

In this activity, you will read about the types of mining conducted in New York and the ways that it is regulated. Then, you will compare New York's mining with the coal mining happening in Appalachia and construct an argument about why New York has fewer environmental and health impacts from mining than Appalachia.

Step 1. Read and annotate the text
While you read the text, annotate it by:

- Putting (+) next to benefits of New York's mining regulations
- Putting (-) next to costs of New York's mining regulations

Mining in New York State

In New York, mineral mining is worth about $1.87 billion as of 2020; it ranks first in the nation for garnet (a semi-precious stone) production and third for salt. There is also oil and gas pumping, for a combined value of $28.4 million.

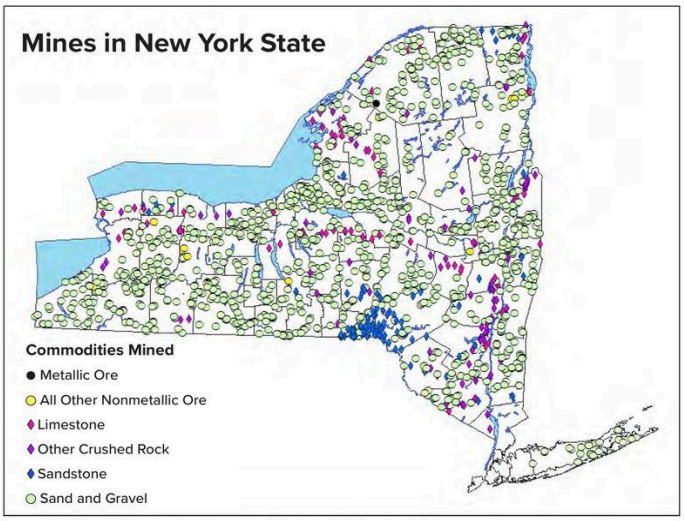


Figure 8 – Map of Mines in New York State

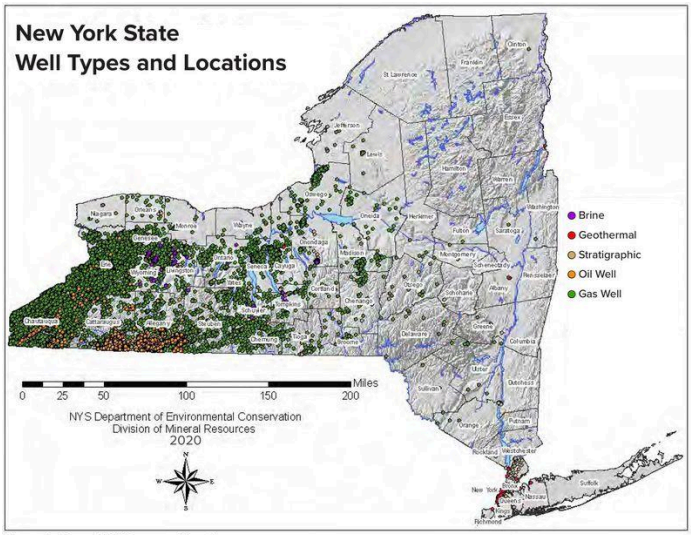


Figure 4 – Map of Well Types and Locations

One way that New York reduces the impact of mining and drilling on the environment is to require that all mines have an approved use and reclamation plan before they are granted a permit. The state requires rigorous planning when a company applies for a mining permit, turning down applications that don't sufficiently protect the environment. For example, in 2023, New York told a garnet mine looking to expand that its plans were deemed incomplete because they did not sufficiently address concerns surrounding visual impact to the area, protection of wetlands, and environmental impacts of forest removal, among other issues. When a permit is approved, the state holds a security deposit from each mine which is only returned when reclamation is completed; the state seizes the funds from any mining operation that abandons its reclamation responsibilities and uses that money to do the restoration itself. Because mine operators know that they will have to fully reclaim the land once mining is complete, they design mines to minimize disruptions as much as possible; in some cases reclaiming land from one part of a mine while it is ongoing in another area.

Despite these protections, mining still has negative impacts on the environment and on human health in New York. Open pit mines, like those for gravel, garnets, and sand, disrupt ecosystems and vistas while they are operating. Mines produce noise pollution from heavy machinery, and explosives used to break up rocks create dust plumes in the air. In Long Island, waste storage during sand mining has been reported to be polluting the groundwater underneath.

Photo 12 – Rolling Hills Pond Mine – Concurrent reclamation of side slopes around the pond, with active mining occurring in background.

At the same time, some mining operations have shut down as a result of stringent regulations, costing the state money and jobs. The number of permitted mines has declined for 21 years in a row. Though New York has large reserves of oil and gas, drilling has decreased dramatically. This decrease is largely because drilling became more expensive due to bans on fracking, a technology that uses water or liquid CO2 to force gas and oil up out of the ground, but which can cause earthquakes and water pollution. New York, however, has decided that the risks to public health outweigh the economic benefits of these mines.

Step 2. Working in pairs, use the information from this text and the first Explore/Explain phases to compare and contrast mining in New York and Appalachia

	New York	**Appalachia**
Differences		
Similarities		

Step 3.
Construct an argument in response to the prompt: how is the New York mining industry able to reduce its health and ecological impacts compared to the Appalachian mining industry?

In your argument, include:

- The steps New York has taken to minimize the impacts of mining
- How those steps are different than ones taken in Appalachian coal mines
- The extent to which those steps have been effective in mitigating the problems of mining
- Any costs (social, economic, or otherwise) that have been associated with those steps
- The constraints these solutions are working within

Solution A: Switching to Renewable Energy
Source information: Harvard International Review

One way to reduce the health impacts of mining coal and other energy is to stop using these types of fossil fuels to generate electricity by increasing our use of renewable energy sources like solar and wind. Making this change would also reduce the amount of emissions from fossil fuels released into the air, like carbon dioxide and air pollution, helping prevent (or reverse) climate change and improve air quality for millions of people.

However, renewable energy sources require machinery to harness and store the energy, including wind turbines, solar panels, and batteries. All of these items require a different set of mineral resources, called Rare Earth Elements (REEs). Surprisingly, REEs are found all over the world, but they exist in low concentrations in minerals and are very hard to separate from other elements. Extracting and refining them has huge environmental costs to communities and ecosystems around them.

There are two main ways to mine REEs, both of which release toxic chemicals into the environment. The first involves removing topsoil and creating a pond where chemicals are added to dissolve rare earth elements out of the ground, so they can be collected, concentrated, and refined. The other method involves digging holes in the ground to pour those chemicals into instead of removing the topsoil. In both cases, the ponds of chemicals created can leak into groundwater and contaminate waterways. When rare earth element ores mix with the chemicals, they can react to create toxic air, water, and soil pollution. Perhaps most worrying is that rare earth element ores often include radioactive thorium and uranium, which can be released into the environment.

Supply chains for REEs are politically challenging as well. China produces 70% of REEs globally; the United States produces 14%, and other countries produce 6% or less (source). China has used that dominance to try to control other nations: in 2010, it blocked REE exports to Japan as punishment for Japan's detention of a Chinese captain. In 2019, China considered limiting REE exports to the United States in response to tariffs, presenting a tremendous threat since the US defense industry relies heavily on these minerals.

China has been able to get ahead in this industry because it has relaxed environmental regulations that allow polluting mining operations to grow quickly. Those mines have caused significant damage: one mine has resulted in 70,000 tons of radioactive waste that are seeping into the groundwater and towards the Yellow River, which is a key source of drinking water; other mines have caused "cancer villages" to pop up, areas where a disproportionately large number of people have gotten cancer from mining pollution; and workers have developed heart, lung, and skin diseases from working in the mines. Furthermore, China has made agreements with many African countries, including the Democratic Republic of Congo and Kenya, to build mines in those places. Many people are worried that the industrialized world is offloading its dangerous mining to developing countries that will not benefit from them.

Hopefully, these problems won't exist forever as technology improves. The United States is working to create its own REE supply chain and find cleaner ways to extract the elements. Some companies are working to recycle REEs rather than mine new ones, and others are working on renewable energy technology that doesn't require REEs at all. However, at the moment, there are real costs associated with the benefits of renewable

energy. The question is: how do those costs compare to the benefits gained by avoiding fossil fuel mining and burning?

Solution B: Reclaiming Mined Habitats

One way to reduce the impacts of mining coal and other energy and mineral resources is to restore lands once mining is completed. In 1977, the Surface Mining Control and Reclamation Act introduced regulations for active mines and required that abandoned or completed mining sites be cleaned, returned to natural habitat, or used for construction of homes or commercial buildings. This process is called mine reclamation: mines are *reclaimed* for other uses (source). In some cases, mines can even be reclaimed while they are still in use: only certain parts of the mine are used for mining at a time, while the rest is preserved and reclaimed. In reality, reclaiming mines is very complicated and expensive, with a wide range of success.

In best-case scenarios, surface mines have been carefully cleaned, rocks and soil have been returned to recontour the landscape to its original shape, and native plant species have been replanted to reduce biodiversity loss (source). In one particularly successful example in Pennsylvania, a species of Elk, which had been wiped out in the area, returned to reclaimed land (source). In other areas, old coal mines from the 1970s and 1980s had been reforested, but with non-native plants that did not restore original biodiversity; efforts are underway now to replant those areas with more productive species (source).

The active Suffern quarry before reclamation.


View of the erosion control matting installed on a 2:1 slope after cutting and regrading.


View showing the slope with grasses established.

By law, reclamation efforts can also turn old mines into useful areas for humans. By law, mines are supposed to be returned to their original shape, Image source but exceptions are made for reclaimed mines that will have economic use when reclaimed. Mines have been turned into parks, golf courses, and agricultural fields. These uses are better than open mines left behind, but do not restore the natural environment that used to exist.

Reclaiming lands used for mountaintop removal coal mining is particularly challenging. In Appalachia, 500 of the oldest and most biodiverse mountains in the United States have already been destroyed, leaving environmental destruction and toxic chemicals behind. These mines do not simply dig into the surface, but use explosives to remove the entire tops of mountains, so restoring the mountains is particularly challenging. The companies responsible for this destruction have claimed that the land will be converted for economic use, thereby avoiding the need to restore mountains to their original shapes. However, 90% of mined sites have not been reclaimed for economic purposes; instead, they have simply been abandoned (source).

Efforts to reclaim land in Appalachia are underway, however. Projects begun in 2017 have introduced solar farms and water treatment plants to locations across the region (source). In 2021, the Bipartisan Infrastructure Law allotted $11.2 billion to reclaiming abandoned mines, with hundreds of millions of dollars going to the Appalachian region. With that money, states are initiating work to remove mining waste piles, stabilize hills against landslides, clean water sources, and restore watersheds (source). These projects can go a long way in

improving the health of communities impacted by nearby mining operations, but they are undermined by private companies continuing to destroy the environment even while public money tries to clean it up. Mine reclamation has clear benefits, but how do those benefits compare to the cost of implementing them and of ongoing environmental damage from mining?

Reducing the Impacts of Mining

Now that we have fully analyzed the challenges of mining without damaging human health and ecosystems, we will consider two solutions to reduce its impacts. Follow the steps below to evaluate each solution and select one that has better cost-benefit ratios.

First, describe the overall phenomenon.

1. What is the human activity that is causing a problem?

2. Why is it happening? What needs are being met?

3. How is that causing problems? What are the costs to human and ecosystem health?

4. Now, based on what you have read so far, brainstorm some ways to reduce the impacts of human activities.

5. Think about what you'd want a good solution to accomplish. What does a successful solution look like to you? What criteria would be most important to you when comparing solutions?

Read-Generate-Sort Solve Organizer

Guiding prompt: How can we evaluate solutions to real-world problems? The need for energy and mineral resources has continued to increase, but scientists, engineers, and policymakers are constantly trying to reduce human and environmental costs while maintaining benefits. There are many different ways to reduce the impact of mining on human and ecosystem health. Follow the steps of the Read-Generate-Sort-Solve routine below to evaluate two solutions and identify which one has the most preferred cost-benefit ratios.

1. **Read** about each solution and capture your ideas in the note taker below

Solutions:

A. Switching to Renewable Energy
B. Mined Land Reclamation

As you read, capture ideas to fill in the note catcher below

	Solution A	**Solution B**
What are the costs of the solution?		
What are the benefits of the solution?		

What are the strengths of each solution in terms of its costs and benefits? ● economic ● environmental ● Geopolitical		
What constraints exist that the solutions must work within, including cost, safety, reliability, aesthetics, cultural effects, environmental effects?		

2. **Generate** ideas on the prompt: Which solution maximizes benefits while reducing costs the most?

Name: _____	**Name:** _____	**Name:** _____

3. **Sort -** Discuss each solution or idea and ☆star☆ the ideas that seem the most useful

4. **Solve -** Write your group's response to the prompt "Which solution maximizes benefits while reducing costs the most?" incorporating the most useful ideas from the sorting process! To do so, write a logical argument in factor of one of the solutions based on all the factors above.

Use evidence from the investigation and texts in this 5E to support your evaluation.

Reflect:

1. Does this solution affect people equitably? Do some people gain more benefits than others?

2. What changes to the technology or environment would change your opinion on the solutions? What would have to change for you to believe that the other solution is better, or that your choice is no longer best? What improvements could be made to either solution which might change the cost-benefit analysis?

Arguing for Solutions

Read about each one and capture your ideas in the note taker below

Solutions

A. Increased Regulation of Sustainable Practices
B. Reuse Mining Waste

As you read, capture ideas to fill in the note catcher below

	Solution A	**Solution B**
What are the costs of the solution?		
What are the benefits of the solution?		
What are the strengths of each solution in terms of its costs and benefits? ● Economic ● Environmental ● geopolitical		
What constraints exist that the solutions must work within, including cost, safety, reliability, aesthetics, cultural effects, environmental effects?		

Brainstorm ideas on the prompt: Which solution maximizes benefits while reducing costs the most?

Write a logical argument in factor of one of the solutions based on all the factors above.
Use evidence from the investigation and texts in this sequence to support your evaluation.

What changes to the technology or environment would change your opinion on the solutions? What would have to change for you to believe that the other solution is better, or that your choice is no longer best? What improvements could be made to either solution which might change the cost-benefit analysis?

Evaluate Mining Student Texts

Solution A: Increased Regulation of Sustainable Practices

Because coal is a valuable resource that is known to cause many health and environmental problems, many organizations try to find a middle ground by advocating for maintaining the coal industry but increasing regulations that promote sustainability. In some ways, the United States has begun that process: In 1977, a law passed called the Surface Mining Control and Reclamation Act, which required reclamation of abandoned mines and set requirements that new mining operations be set up "in an environmentally friendly manner." However, many people argue that its requirements are not strict enough, and enforcement of the law has been largely left to states, not all of which uphold it strictly. Different regulatory bodies within the United States have continuously added or removed environmental protections over the past 50 years, resulting in a patchwork of active and inactive regulations and uneven regulation over time.

Globally, the mining industry reports that it has become more sustainable overall. Technology has become more efficient, and some areas are switching over to energy-efficient machinery and vehicles to reduce the overall carbon footprint of mining operations. Some mines use water recycling technology to reduce the water burden on local areas, and others capture methane gas that would otherwise pollute the air and use it for energy. However, none of these strategies fundamentally change how mines interact with ecosystems.

Within the United States, many advocacy groups are arguing for more stringent regulations on coal mining. Some groups are campaigning to end mountaintop removal coal mining entirely, while others are lobbying to restrict its use to areas where it would not interfere with natural features like streams. Opponents of regulations say that these limitations would result in the end of coal mining in appalachia completely; though traditional underground mining using tunnels has become safer and produces a much smaller footprint than mountaintop removal, so much coal has already been extracted from appalachia that the remaining coal is too sparse to be mined using tunnels. As a result, there is disagreement about whether mining can be made healthy and environmentally friendly at all.

Solution B: Reusing Mining Waste

Modified from the Washington Post and The Journal of Minerals Engineering

Though it is well-established that coal mining, especially across Appalachia, has caused huge amounts of damage, cleaning up dangerous mining pollution has been challenging and very expensive. For example, in West Virginia alone, there are 184 water treatment plants costing $4 million per year, working to clean up acid mine drainage, a type of pollution from coal mines that contaminates drinking water and kills organisms. One report has estimated that cleaning up all of the abandoned coal mines around the country would cost $20 billion. However, new initiatives are working to reuse waste from coal mining, helping reduce the pollution footprint of those mines and create commercially useful other products.

One such reuse project is to extract value from acid mine drainage itself. This corrosive pollutant happens to be high in minerals, including cobalt, nickel, and rare earth elements. A new recycling plant near the Potomac River in West Virginia plans to clean acid mine drainage pollution and recapture those pressures metals and other minerals. Researchers hope that, over time, the financial gain of recovering these minerals, which are needed for building cell phones and other electronics, will cover the cost of cleaning up the pollution itself. Other projects are trying to mine rare earth elements from solid coal mining waste. Research indicates that land displaced from coal mines could contain 300 to 400 tons of rare earth elements. Using these wastes to gather rare earth elements would help the United States gain an important supply of these elements, which currently come mostly from China, and reduce the need to open new mines for these valuable supplies.

Coal mining produces large amounts of waste rock and dirt, which are often displaced and left disrupting natural landscapes. Around the world, these waste rocks are recycled and used to create bricks and other construction materials. Recently, scientists have improved that process to extract residual coal from these waste rocks and construct new bricks with the remaining waste, which both maximizes the coal resources gained from mining and creates strong building materials.

Neither of these solutions solve all of the problems associated with coal mining and its resultant pollution, but if mines operated with plans for safely disposing of their waste before it becomes environmentally-damaging, their overall footprints would be decreased

Mining Performance Task Rubric

Mining	Proficient	Developing
Argument Rubric	Effectively and clearly provides an evaluation of the presented competing solutions that includes **all** of the elements below: ● A description of the real world problem ● An explanation of how the solution helps with the real world problem, using empirical evidence and scientific ideas ● An identification of the ways solution does not fully solve the real world problem ● An analysis of the tradeoffs of the solution, including economic, societal, and/or ethical considerations ● An argument for the use of one or more competing solutions using the relevant evidence and scientific ideas supporting each solution and its drawbacks	Provides an evaluation of the presented competing solutions that includes **some** of the elements below: ● A description of the real world problem ● An explanation of how the solution helps with the real world problem, using empirical evidence and scientific ideas ● An identification of the ways solution does not fully solve the real world problem ● An analysis of the tradeoffs of the solution, including economic, societal, and/or ethical considerations ● An argument for the use of one or more competing solutions using the relevant evidence and scientific ideas supporting each solution and its drawbacks
Connections to Engineering, Technology, and Applications of Science	Argument includes data that shows to what extent the solution can reduce or reverse the negative changes caused by land use	Argument does not include data that shows to what extent the solution can reduce or reverse the negative changes caused by land use
Student Self-Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:
Teacher Score	**Circle One**	**Glow**: **Grow**:

	Proficient **Developing**	

Relevance to your life: Think about everything that you have learned throughout this unit so far.

1. What is one idea and/or skill you learned that you think is important to teach someone in your family or community?

2. To whom do you intend to teach this idea and/or skill? Why do you think it is important for this person to learn this idea and/or skill?