Lesson 4: What makes an energy source reliable?

Previous Lesson *We read about an energy crisis that began in Ohio, and a strategy used by engineers to prevent short and broken circuits in power lines. We kept track of our ideas for design solutions in the Engineering Design Tracker. We developed a new representation to model energy transfer through systems. We analyzed data about electricity supply and demand in Texas, and we noticed a drop in supply during the blackout. We brainstormed about what could have caused that drop in supply.*

This Lesson

Investigation

2 days

US Marine Corps, Pfc. J. Handeland

We look at energy sources used in Texas, and consider what we know about each. We use informational cards to seek additional information about specific sources of energy to help us figure out which source might be responsible for the drop in supply we discovered in Lesson 3. We rank the sources by reliability, but realize that this criterion is hard to quantify. We look at several data representations from the 2021 Texas crisis to analyze how each energy source performed. We use a new tool called Decisions Matrix to keep track of how well each source meets criteria we think are important.

Next Lesson *We will use diagrams of power plants to figure out how they transfer energy into wires, which makes us wonder what is happening inside generators. We will dissect a generator, then build our own, and use compasses to investigate fields. Lastly, we will model energy transfer through fields inside our generators, and make connections between matter and energy to refer to as we move forward.*

BUILDING TOWARD NGSS

HS-PS2-5, HS-PS3-1, HS-PS3-2, HS-PS3-3, HS-PS3-5, HS-ESS3-2, HS-ETS1-3, HS-ETS1-4

What students will do

4.A Analyze multiple types of data to identify characteristics of energy sources derived from Earth's systems that increase the reliability of the energy grid (a criterion for success), given that for the system to remain stable, it must be designed for energy supply to meet energy demand. (SEP: 4.6; CCC: 7.4; DCI: ESS3.A.2; DCI: PS3.B.4)

What students will figure out

- The energy used to create electricity in a power plant comes from Earth's systems.
- Making decisions about complex societal issues like energy production requires defining criteria for success that might not be

straightforward or easy to quantify.

Lesson 4 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	8 min		**NAVIGATE** Based on exit tickets from Lesson 3, take a look at energy sources in Texas, consider what we already know about energy sources, and discuss what we want to know more about.	A-C	*Texas Power Stations* (optional)
2	15 min		**RANK ENERGY SOURCE CARDS** Students rank *Source Cards Full Page* using criteria that they believe contribute to reliability.	D-E	*Source Cards Full Page* or *Energy Source Cards*
3	5 min		**CONDUCT A RANKING GALLERY WALK** Conduct a quick gallery walk of card rankings, asking students to take notes on what factors they think other groups used in their decision-making.	F	*Source Cards Full Page* or *Energy Source Cards*
4	15 min		**LEAD AN INITIAL DISCUSSION ABOUT RELIABILITY** Discuss patterns from the gallery walk as a class. Make a poster about the factors that are important for reliability. Develop a class working definition of *reliability*.	G-H	chart paper, markers
5	2 min		**NAVIGATE: EXIT TICKET** Navigate with an exit ticket to motivate looking at additional data about how the energy sources performed in Texas in February 2021.	I	piece of paper for an exit ticket
					End of day 1
6	2 min		**NAVIGATE: TURN AND TALK** Navigate with a Turn and Talk that connects to the exit ticket from day 1. Motivate looking at additional data about how these energy sources performed in Texas in February 2021.	J	
7	15 min		**ANALYZE ENERGY SOURCE SUPPLY GRAPHS** Review patterns in electricity supply data as a class. Analyze graphs of electricity production by energy source in February 2020 and February 2021.	K-N	*Electricity Production 2021*, *Electricity Sources Comparison*
8	15 min		**LEAD A BUILDING UNDERSTANDINGS DISCUSSION ABOUT RELIABILITY OF SPECIFIC ENERGY SOURCES**	O	

		Bring the class back together to discuss patterns in the data. Analyze the performance of different energy sources before and during the blackout.		
9	8 min	**INTRODUCE THE DECISIONS MATRIX** Revise the rankings using our new ideas. Introduce the *Decisions Matrix* and brainstorm criteria to include in it.	P-Q	*Decisions Matrix*, *Source Cards Full Page*
10	5 min	**NAVIGATE** Revisit the "Moving our science thinking forward" category of our Community Agreements. Then have students turn and talk about the missing information from the *Source Cards Full Page*.	R-S	Community Agreements poster (from Lesson 1), *Source Cards Full Page*

End of day 2

Lesson 4 • Materials List

	per student	per group	per class
Lesson materials	• *Texas Power Stations* (optional) • science notebook • piece of paper for an exit ticket • *Electricity Production 2021* • *Electricity Sources Comparison* • *Decisions Matrix*	• *Source Cards Full Page* or *Energy Source Cards* • *Source Cards Full Page*	• chart paper • markers • Community Agreements poster (from Lesson 1) • *Source Cards Full Page*

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to students' notebooks.

Print the *Source Cards Full Page*. *Energy Source Cards* is formatted to print two pages to a sheet, double-sided (in color if possible). The PDF version will format correctly, but the Google Doc will not. If you must print from a Google Doc, or cannot print double-sided, use *Source Cards Full Page*.

Prepare chart paper for a poster titled:

- Factors that May Impact Reliability

Lesson 4 • Where We Are Going and NOT Going

This lesson is designed to coherently build ideas related to the following disciplinary core ideas:

- **PS3.B.4 Conservation of Energy and Energy Transfer.** The availability of energy limits what can occur in any system. (HS-PS3-1)
- **ESS3.A.2 Natural Resources.** All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

This lesson introduces a new scaffold, the *Decisions Matrix*, which students will use alongside the Engineering Design Tracker in Lesson Set 2 to make decisions about what designs they would like to advocate for in their community as the electric grid ages.

Students will encounter or co-develop definitions for the following words in this lesson: *reliability, efficiency, power, dispatchability.* **Do not** post any words or ask students to add them to their Personal Glossaries until after the class has developed a shared understanding of their meaning.

LEARNING PLAN for LESSON 4

1 · NAVIGATE

8 min

MATERIALS: *Texas Power Stations* (optional)

Reflect on where we wanted to go next. Project **slide A**. Remind students that at the end of the last class, we completed an exit ticket. Tell them that most people wanted to know more about the sources of energy in Texas, because we saw a big drop in energy supply in February 2021.

Ask students to turn and talk about the prompts on the slide:

- What energy sources have you heard about?
- What energy sources do you expect to see being used in Texas? Why?

After 1-2 minutes, bring the class back together and elicit their ideas using the table below.

Suggested prompt	Sample student response
What are some energy sources you have heard about?	(Accept all responses.)
What do you expect to see being used in Texas, and why?	There is a lot of open space in Texas. Maybe solar? I've heard Texas has a lot of oil and other resources. Maybe those are being used.

Introduce Texas energy sources. Show **slide B**. Ask students to first notice and wonder individually about the map of energy sources in Texas. This map is also provided in *Texas Power Stations*, which can be distributed to each student if you wish. Elicit noticings and wonderings after a minute.

Expected noticings:

- There are a lot of solar power plants, wind power plants, and natural gas power plants.
- There are also some coal, biomass, and hydroelectric plants, and about two nuclear plants.
- Some areas have more of one type of power plant than another, but overall they are fairly well distributed.

- It doesn't look that different from the surrounding states.

Expected wonderings:

- Why are some power plants in some places and not others?
- Why are there only two nuclear plants?
- Why is there more of some kinds of power than others?
- Did any of these power sources fail in February 2021?

Present **slide C**. Ask students to turn and talk about the prompts on the slide. After 1-2 minutes, bring the class back together to discuss, using the table below. Accept all student ideas without judgment.

Suggested prompt	Sample student response
What do you know about some of these energy sources?	Coal comes from the ground, and gets burned. Windmills turn generators, and only work when it is windy. Natural gas is what we use to heat our homes. Solar uses solar cells to make electricity.
Could any of these sources have contributed to the crisis in 2021? How?	Maybe windmills froze. Maybe it was too cold to burn coal. Maybe natural gas pipelines froze. Maybe there was no sun because of the storm.
What data could help us understand whether any of these sources might have been responsible for the 2021 crisis?	Could we see how much electricity each one produced in February 2021?

2 · RANK ENERGY SOURCE CARDS

15 min

MATERIALS: science notebook, *Source Cards Full Page* or *Energy Source Cards*

Get familiar with the *Source Cards Full Page* in groups. Have students gather in groups of 3–4, and distribute a set of *Source Cards Full Page* or *Energy Source Cards* to each group. Project **slide D**. Read the prompts on the slide aloud:

- *From which of Earth's systems are most of these sources extracted?*
- *What clues can you find that might help us understand which sources were unreliable in February 2021?*

Tell students to examine the cards and discuss the slide's questions for a few minutes. Move around the room to assess students' thinking as they talk.

ASSESSMENT OPPORTUNITY

What to look for/listen for: As you move around the room, listen for students to make the connection that almost all of these sources come from Earth's systems, except solar. (DCI: ESS3.A.2)

What to do: Use questions about specific systems (the air, the ground, the water, life) to support students in making those connections.

As students discuss the second question, listen for ideas about which factors might contribute to reliability/unreliability, including efficiency, dispatchability, power, and specific mechanisms related to the sources' production of energy; accept these ideas without judgment.

Building toward: 4.A.1 Analyze multiple types of data to identify characteristics of energy sources derived from Earth's systems that increase the reliability of the energy grid (a criterion for success), given that for the system to remain stable, it must be designed for energy supply to meet energy demand. (SEP: 4.6; CCC: 7.4; DCI: ESS3.A.2, PS3.B.4)

Rank the *Source Cards Full Page* in groups. Project **slide E** and go over the directions on the slide:

- *Which information do you think is the most important for determining which energy sources are reliable? Why?*
- *Rank the energy sources from least to most reliable, using the factors you identified as important.*

Give students about 5 minutes to rank the energy sources at their tables. Ask students to write down their rankings in their science notebooks. Expect them to disagree about how to rank the sources. As students work, circulate and make note of the rankings. Ask them why they are making those decisions, and what additional data they would need to better inform their decisions.

Bring the class together. Point out that it seems groups have made different decisions regarding the energy sources we are examining.

3 · CONDUCT A RANKING GALLERY WALK

5 min

MATERIALS: science notebook, *Source Cards Full Page* or *Energy Source Cards*

Conduct a ranking gallery walk. Project **slide F**. Ask students to create a T-chart in their notebooks like the one on the slide. Quickly number or name each group to make it easier for students to record their notes in this chart.

Have students do a gallery walk, moving from table to table to observe the rankings of other groups. Instruct them to try to determine what factors each group used to assess the reliability of the energy sources, and write those in their chart.

4 · LEAD AN INITIAL DISCUSSION ABOUT RELIABILITY

15 min

MATERIALS: science notebook, chart paper, markers

Discuss patterns from the gallery walk as a class. Project **slide G**. Ask students to return to their seats. Have students share out any rankings that they noticed were different from theirs, and what they think that group was using as criteria in their ranking system. Verify the rankings with the group in question, and discuss how the class saw different factors contributing to the reliability of an energy source.

Make a poster about what factors are important for reliability. Focus attention on the last question on the slide. Prepare a new sheet of chart paper for this question, titled "Factors that May Impact Reliability". Have students share out while you record their ideas. Listen for them to mention things like efficiency, power, dispatchability, or mechanisms related to how the resource is extracted.

Develop a class working definition of reliability. Project **slide H**. Ask students to turn and talk about the prompts on the slide for about 2 minutes:

- What does it mean for an energy source to be reliable?
- Why is high reliability such an important criterion for making decisions about energy?

Then bring the class back together to discuss the first prompt. Listen for students to suggest that reliability means stability, predictable change, or supply consistently meeting demand.

ADDITIONAL GUIDANCE

If students settle on a definition about stability (e.g., doesn't change much, always stays high, never goes down), push them to make a connection to the supply and demand graphs:

- *In the graphs from 2020 that we looked at in Lesson 3, there were still a lot of ups and downs. Are you saying energy supply was unreliable in February 2020 as well?*
- *What was unique about February 2021 that meant people lost power, that can help us define reliability?*

Discuss how we change reliability into a criterion. Before discussing the second prompt, ask students to look back at their Personal Glossaries to remind themselves of what a criterion is; you may need to point out that *criterion* is the singular of *criteria* to support them in making that connection.

Say, *How can we reframe reliability to be a criterion we want to meet with the design of our electric grid? We don't have a way to quantify it, but we can say whether we want it to be higher or lower.* Listen for students to say we want reliability to be high.

Then ask students for their ideas about the second prompt on the slide. Listen for them to point out that power outages are dangerous, and that providing power in a predictable, stable way is the fundamental purpose of the electric grid.

Add new terms to students' Personal Glossaries. Give students a minute to add *reliability* to their Personal Glossary. They should also take the time to add words they encountered in their cards and listed on the Factors that May Impact Reliability poster, such as *efficiency*, *power*, and perhaps *dispatchability*.

ASSESSMENT OPPORTUNITY

What to look for/listen for: Students can explain that in order for the system to remain stable, it must be designed for supply to meet demand. (CCC: 7.4; DCI: PS3.B.4)

What to do: Use the crosscutting concept of stability and change to support student sensemaking. Remind students that in Lesson 3, they saw that energy supply and demand matched before the energy crisis (stability), and that the gap between supply and demand was the largest during the blackout (change). Use this framing to help students draw connections between the stability of an electric grid system and its reliability.

Building toward: 4.A.2 Analyze multiple types of data to identify characteristics of energy sources derived from Earth's systems that increase the reliability of the energy grid (a criterion for success), given that for the system to remain stable, it must be designed for energy supply to meet energy demand. (SEP: 4.6; CCC: 7.4; DCI: ESS3.A.2; PS3.B.4)

5 · NAVIGATE: EXIT TICKET

2 min

MATERIALS: piece of paper for an exit ticket

Assign an exit ticket to motivate looking at additional data. Distribute a piece of paper to each student and project **slide I**. Pose the question on the slide aloud as an exit ticket: *What additional data or information do we want to see that can help us figure out which energy sources contributed to the crisis in February 2021?* Have students write their name and their answer(s) to turn in before they leave.

Look at the exit tickets for students who write about the performance of those sources in Texas in February 2021, which will be a great transition into the work we do next. Take note of who these students are, and call on them on day 2 to ease that transition. However, if nobody brings this up, that is not a problem; simply take note of what students are interested in investigating next.

End of day 1

6 · NAVIGATE: TURN AND TALK

2 min

MATERIALS: None

Navigate with a Turn and Talk to motivate looking at additional data. Project **slide J** and read the prompt aloud: *What data about energy in Texas in February 2021 could help us figure out what went wrong, and which sources contributed to the crisis?*

Give students a minute to turn and talk about the slide's question. Listen for a variety of ideas. Then use your notes from day 1's exit tickets to call on students who wrote that they want to look at the performance of those sources in Texas in February 2021, and ask them to share out. Say, *I have supply graphs for each of the sources we have been investigating.*

However, if nobody comes up with that idea directly, that's OK. Use students' other ideas to consider creative ways to introduce that data; for example, if several students suggest that we look at "more data about whether the sources are reliable," you can motivate looking at the data next time by saying, *A lot of people wanted to know more about whether these sources were reliable. I have supply graphs for each of the sources we have been investigating. How could data about how much supply each source contributed in February 2021 help us figure that out?*

7 · ANALYZE ENERGY SOURCE SUPPLY GRAPHS

15 min

MATERIALS: *Electricity Production 2021*, *Electricity Sources Comparison*, science notebook

Review patterns in supply. Say, *Before we look at supply graphs for each of the sources we have been investigating, let's remind ourselves what a graph of energy supply looks like.*

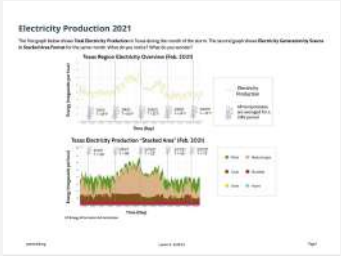
Present **slide K**. Remind students that we looked at this graph in Lesson 3, and that we were concerned about the gap between how much energy was being supplied and how much energy people wanted to use. ✱

Then pose the question on the slide:

- *What patterns would we expect to see from a source that contributed to the drop in supply?*

Listen for students to suggest looking for a pattern that follows the pattern in the graph of supply (the yellow line). Say, *I made sure to include a graph of supply alongside the graphs for each individual source, so we can compare those patterns.*

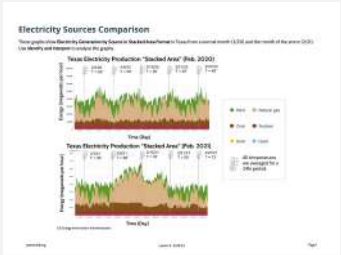
Use a Stand and Talk protocol to find new partners. Project **slide L**. Ask students to stand up and find a partner that they have not worked with before. Once a student has found a new partner, give them *Electricity Production 2021*. Then give the partner pairs 3 minutes to make observations and formulate questions.



Discuss how the information is presented. Bring the class back together to briefly answer questions about the graphs that will allow students to dig deeper into the data in the next Stand and Talk. Then point out that this kind of data can be presented in multiple ways. Display **slide M**.

Ask students what they notice and wonder about the way this data is presented in each graph. Listen for ideas about how the stacked area graph shows the same data, but in a different way. Spend a couple of minutes checking in with students to ensure that these representations make sense to them. Guide them to compare the bottom graph with the top graph, and to reason out that the comparison shows that the amounts of energy from each source have been stacked on top of each other, not layered on top. This means that natural gas produced the most energy in this time period, and nuclear produced the least.

Analyze graphs of electricity production in February 2021. Project **slide N**. Say, *Let's compare this data from 2020, when there was no crisis, to data from February 2021, and see what we notice.* Ask students to do another Stand and Talk to find a new partner, and prepare a T-chart in their science notebook like the one on **slide N**, titled "February Data." Distribute *Electricity Sources Comparison* to each student once they have formed a new pair. Give them 5 minutes to work with their new partner to fill in their T-charts according to the slide's instructions.



As students are working, circulate among the partner pairs. Specifically, listen for ideas related to:

- Coal was variable in February 2020, but consistent during the blackout.

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

Take this opportunity to reinforce what we figured out in Lesson 3 related to the disciplinary core idea PS3.B: Conservation of Energy and Energy Transfer. Remind students that because energy is a conserved quantity, if sufficient energy is not supplied to the system, there is no way to create more energy for the system to function.

✱ SUPPORTING STUDENTS IN ENGAGING IN OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION

Over the course of the OpenSciEd physics program, students will see multiple representations of the same data set. Make it explicit that looking at multiple representations can help scientists and engineers see new things in the data. Throughout this course, students will continue to look at a variety of graphical representations and data sets to compare, integrate, and evaluate multiple data sources to address a scientific question or solve a problem.

- During the blackout, natural gas increased and wind decreased. This did not happen during the previous year.
- Wind was variable and present in February 2020, but during the blackout it was almost nonexistent.
- Nuclear stayed consistent throughout most of February on both graphs.
- Everything decreased at the same time on the 15th during the blackout.

As you move around the room, ask students how the energy production graphs compare to the prevalence of sources we saw on the Texas map (i.e., a lot of windmills, only two nuclear power plants). ✱

8 · LEAD A BUILDING UNDERSTANDINGS DISCUSSION ABOUT RELIABILITY OF SPECIFIC ENERGY SOURCES

15 min

MATERIALS: None

Discuss patterns in the data. Bring the class back together and present **slide O**. Use the questions on the slide (in the table below) to build understanding about important patterns in the graphs.

Suggested prompt	Sample student response
How are the patterns in February 2021 different from the patterns in February 2020, and across the year?	In 2020, February was relatively consistent with the other months--even in the summer, the supply stayed relatively consistent across the energy sources, with variability in natural gas. In February 2021, every source dropped significantly. Nuclear maybe stayed consistent, but it was a small amount of the total power generated. Solar is always variable, regardless of storms.
How does this help us understand how each energy source may have contributed to the crisis?	Windmills and natural gas both went down, and several other sources did, too. Maybe that contributed to what happened?

Motivate a second look at reliability. There is no need to come to consensus on which sources performed the best, as the answer to that question is complex. Use this conversation to expose that complexity, and establish that no single source was responsible for the crisis.

Say, *It sounds like we can't point a finger at a single energy source, because almost every source was affected to some degree, and Texas relies on each of them in different ways. But we do have some ideas about which sources might be more reliable in a crisis like this one.*

ASSESSMENT OPPORTUNITY

What to look for/listen for: Students identify patterns in the data, and can explain what they mean, relating their ideas back to reliability. (SEP 4.6)

What to do: Continually press students to justify their reasoning using the data, with prompts such as:

- *Can you show me what pattern led you to that conclusion?*
- *How does the pattern you pointed to tell us about reliability?*

Building toward: 4.A.3 Analyze multiple types of data to identify characteristics of energy sources derived from Earth's systems that increase the reliability of the energy grid (a criterion for success), given that for the system to remain stable, it must be designed for energy supply to meet energy demand. (SEP: 4.6; CCC: 7.4; DCI: ESS3.A.2; PS3.B.4)

9 · INTRODUCE THE DECISIONS MATRIX

8 min

MATERIALS: *Decisions Matrix*, *Source Cards Full Page*

Return to our rankings. Suggest that it might be time to revisit our rankings from earlier, given what we now know. Present **slide P**. Get students back into their original groups, and make sure they still have their set of *Source Cards Full Page*. Give them about 5 minutes to rethink their rankings, based on the graphs, and to reacquaint themselves with the cards.

Introduce the *Decisions Matrix*. Project **slide Q**. Explain that eventually, we want to be able to advocate for systems in our own community that are reliable, using lessons learned from Texas; so, we should keep track of what we figure out about how well these sources meet the criteria we set.

Distribute *Decisions Matrix* to every student. Point out that there is space in the top row for a variety of criteria, and ask students to write "High reliability" in the first box (under #1). Explain that we will record new rankings by writing the names of the energy sources in the left-hand column, and then using numbers, stars, or a rating system to record how well the sources meet that criterion.

Through a brief discussion, establish the ranking system that the class will use to evaluate the energy sources. Note that students might have seen a *Decisions Matrix* before, especially if they have engaged with middle school materials such as *Collisions Unit*, *Tsunami Unit*, or *Homemade Heater Unit*.

Add criteria to the matrix. Ask students whether we might want to include any other criteria that came up in our investigations over the past few days. Suggest that they look back at the factors they recorded in their notebooks during the gallery walk, the Factors that May Impact Reliability poster, and/or the *Source Cards Full Page*. As students suggest a factor, ask them to frame the heading in terms of a criterion, e.g., "High efficiency" rather than "Efficiency." Then ask students to fill in that column.

10 · NAVIGATE

5 min

MATERIALS: Community Agreements poster (from Lesson 1), *Source Cards Full Page*

Revisit the "Moving our science thinking forward" category of our Community Agreements. Present **slide R**. Point to the Community Agreements poster and say, *Today we did not all agree at first on how to rank the energy sources, but we managed to move forward. How did your peers help move your science thinking forward today?* Accept all ideas.

Then ask the next two questions on the slide:

- *Which Community Agreements should we prioritize in that category?*
- *What are some things we should consider next time to make sure our science thinking moves forward?*

Listen for responses such as:

- We should hold ourselves accountable for staying engaged.
- We should have fun but make sure we are being productive.
- We should be willing to throw things at the wall and see whether they stick.

ALTERNATE ACTIVITY	If there is time, consider having students gather around the Community Agreements poster, and use sticky dots or check marks to indicate which agreements they think we should prioritize.

Discuss missing information from the *Source Cards Full Page*. Project **slide S**. Ask students to look at the energy transfer diagrams on their group's *Source Cards Full Page*, and then read the slide's prompt aloud:

- What information is missing from these diagrams that could help us understand why energy sources are more reliable (or efficient,

powerful, dispatchable)?

Have students turn and talk quickly about this question before leaving.

Additional Lesson 4 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

These are the CCSS related ideas that are used to support sensemaking in this lesson:

- **CCSS.ELA-Literacy.RST.11-12.2.** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Students do this when they synthesize the information from the *Source Cards Full Page* to develop the energy transfer model for each energy source.

- **CCSS.ELA-Literacy.RST.11-12.5.** Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.

Students do this by sorting the *Source Cards Full Page* into different categories using the information presented in the text.