# Introduction

# Formative Assessment Exemplar - CHEM.4.5

**Introduction:**

The following formative assessment exemplar was created by a team of Utah educators to be used as a resource in the classroom. It was reviewed for appropriateness by a Bias and Sensitivity/Special Education team and by state science leaders. While no assessment is perfect, it is intended to be used as a formative tool that enables teachers to obtain evidence of student learning, identify gaps in that learning, and adjust instruction for all three dimensions (i.e., Science and Engineering Practices, Crosscutting Concepts, Disciplinary Core Ideas) included in a specific Science and Engineering Education (SEEd) Standard.

In order to fully assess students' understanding of all three dimensions of a SEEd standard, the assessment is written in a format called a cluster. Each cluster starts with a phenomenon, provides a task statement, necessary supporting information, and a sequenced list of questions using the gather, reason, and communicate model (Moulding et al., 2021) as a way to scaffold student sensemaking. The phenomenon used in an assessment exemplar is an analogous phenomenon (one that should not have been taught during instruction) to assess how well students can transfer and apply their learning in a novel situation. The cluster provides an example of the expected rigor of student learning for all three dimensions of a specific standard. In order to serve this purpose, this assessment is NOT INTENDED TO BE USED AS A LESSON FOR STUDENTS.

Because this assessment exemplar is a resource, teachers can choose to use it however they want for formative assessment purposes. It can be adjusted and formatted to fit a teacher's instructional needs. For example, teachers can choose to delete questions, add questions, edit questions, or break the tasks into smaller segments to be given to students over multiple days.

Of note: All formative assessment clusters were revised based on feedback from educators after being utilized in the classroom. During the revision process, each cluster was specifically checked to make sure the phenomena was authentic to the DCI, supporting information was provided for the phenomena, the SEPs, CCCs, and DCIs were appropriate for the learning progressions, the cluster supported student sensemaking through the Gather, Reason, and Communicate instructional model, and the final communication prompt aligned with the cluster phenomena. As inconsistencies were found, revisions were made to support student sensemaking. If other inconsistencies exist that need to be addressed, please email the current Utah State Science Education Specialists with feedback.

**General Format:**

Each formative assessment exemplar contains the following components:

1. Teacher Facing Information: This provides teachers with the full cluster as well as additional information including the question types, alignment to three dimensions, and answer key. Additionally, an example of a proficient student answer and a proficiency scale for all three dimensions are included to support the evaluation of the last item of the assessment.
2. Students Facing Assessment: This is what the student may see. It is in a form that can be printed or uploaded to a learning platform. (Exception: Questions including simulations will need technology to utilize during assessment.)

**Accommodation Considerations**:

Teachers should consider possible common ways to provide accommodations for students with disabilities, English language learners, students with diverse needs or students from different cultural backgrounds. For example, these accommodations may include: Providing academic language supports, presenting sentence stems, or reading aloud to students. All students should be allowed access to a dictionary.

**References:**

Moulding, B., Huff, K., & Van der Veen, W. (2021). *Engaging Students in Science Investigation Using GRC*. Ogden, UT: ELM Tree Publishing.

# Teacher Facing Info

**Teacher Facing Information**

**Standard:** CHEM.4.5

**Assessment Format:** Online Only (Requires students to have online access), Printable or Online Format (Does not require students to have online access)

| **Phenomenon** | |
|---|---|
| Tellurium is in high demand and is used in new solar panels. The company Rio Tinto is deciding whether to mine Tellurium at their Utah-based Kennecott mine. | Proficient Student Explanation of Phenomenon:<br><br>Criteria: Students will identify criteria based on how much it costs, how much is produced, and environmental impacts, and societal impacts<br><br>Identify Trade-offs: Students identify trade-off between different sources of energy |
| **Cluster Task Statement** | |
| In the questions that follow, you will develop an argument from evidence to make and defend claims regarding potential solutions to a real-world challenge. Use the information from the passage and arguments below to develop *your* argument. | |
| **Supporting Information** | |
| **Passage 1: Taken from a newspaper article published May 11, 2022 by the news source KSL.**<br>*One of the rarest elements on Earth is now in the process of being recovered from Utah's Rio Tinto Kennecott copper mine as a byproduct of copper smelting.*<br><br>*That element is tellurium — which will be produced to the tune of approximately 20 tons annually — through a new $2.9 million circuit built at the Kennecott refinery. This production puts Kennecott in an exclusive group, becoming one of only two U.S. producers of tellurium, a critical mineral used in advanced thin-film photovoltaic solar panels.*<br><br>**Passage 2: Taken from the Rio Tinto website May 11, 2022.**<br>*Tellurium is listed as a critical mineral by the U.S. Government due to its importance to the economy and energy security.*<br><br>*Tellurium is one of ten metals and products recovered from ore extracted at Kennecott, which produces nearly 15 percent of U.S. copper with the country's lowest carbon footprint.*<br><br>*Saskia Duyvesteyn, chief adviser for copper research and development at Rio Tinto Kennecott, says "From an overall carbon footprint, if you think about it, so much of the energy comes from the mining process and the smelting process, we actually make some energy," Duyvesteyn said. "In this process, we did not add to the carbon footprint and yet we're able to produce extra copper."* | |

**Passage 3: Taken from *Mining Technology* journal May 12, 2022.**

*The tellurium produced will be refined by speciality semiconductors and performance materials producer 5N Plus in North America, under an agreement signed with Rio Tinto.*

*5N Plus will refine tellurium at its facility in Montreal, Canada, and primarily supply the refined tellurium to First Solar, under an existing supply contract between the two parties.*

*"Approximately 90% of the world's tellurium resource is contained in copper ore and no other metal has more critical mineral by-products than copper."*

**Figure 1:**

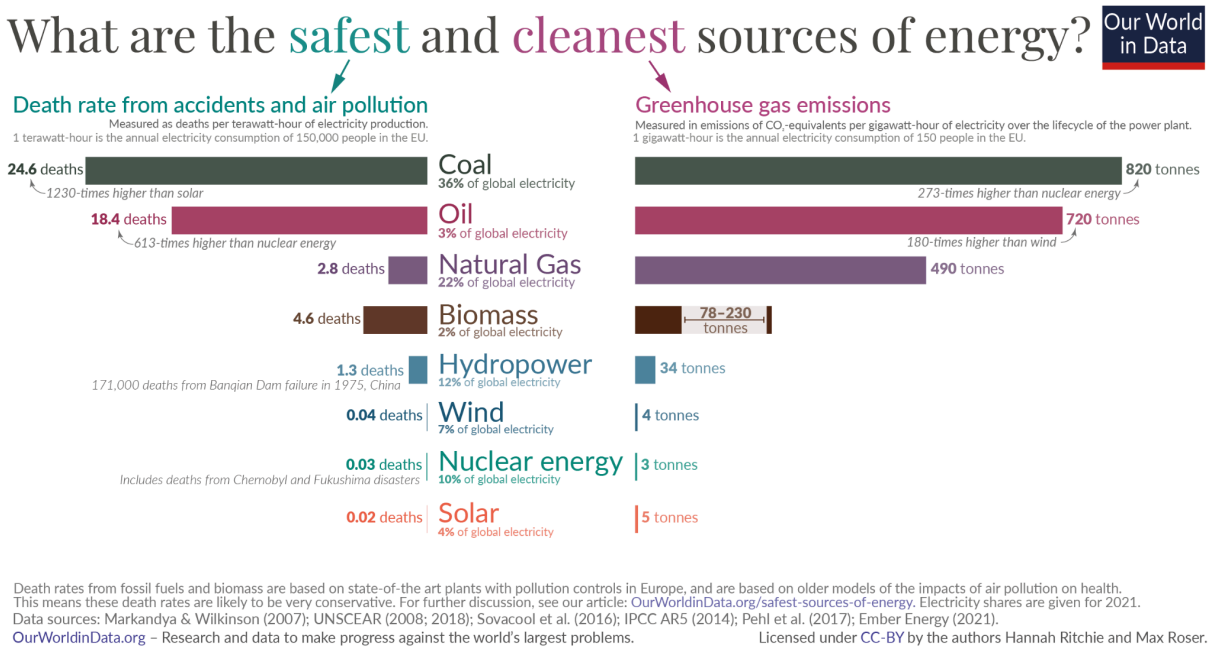



**Table 1: Energy Source and Percentage of Global Electricity taken from Figure 1**

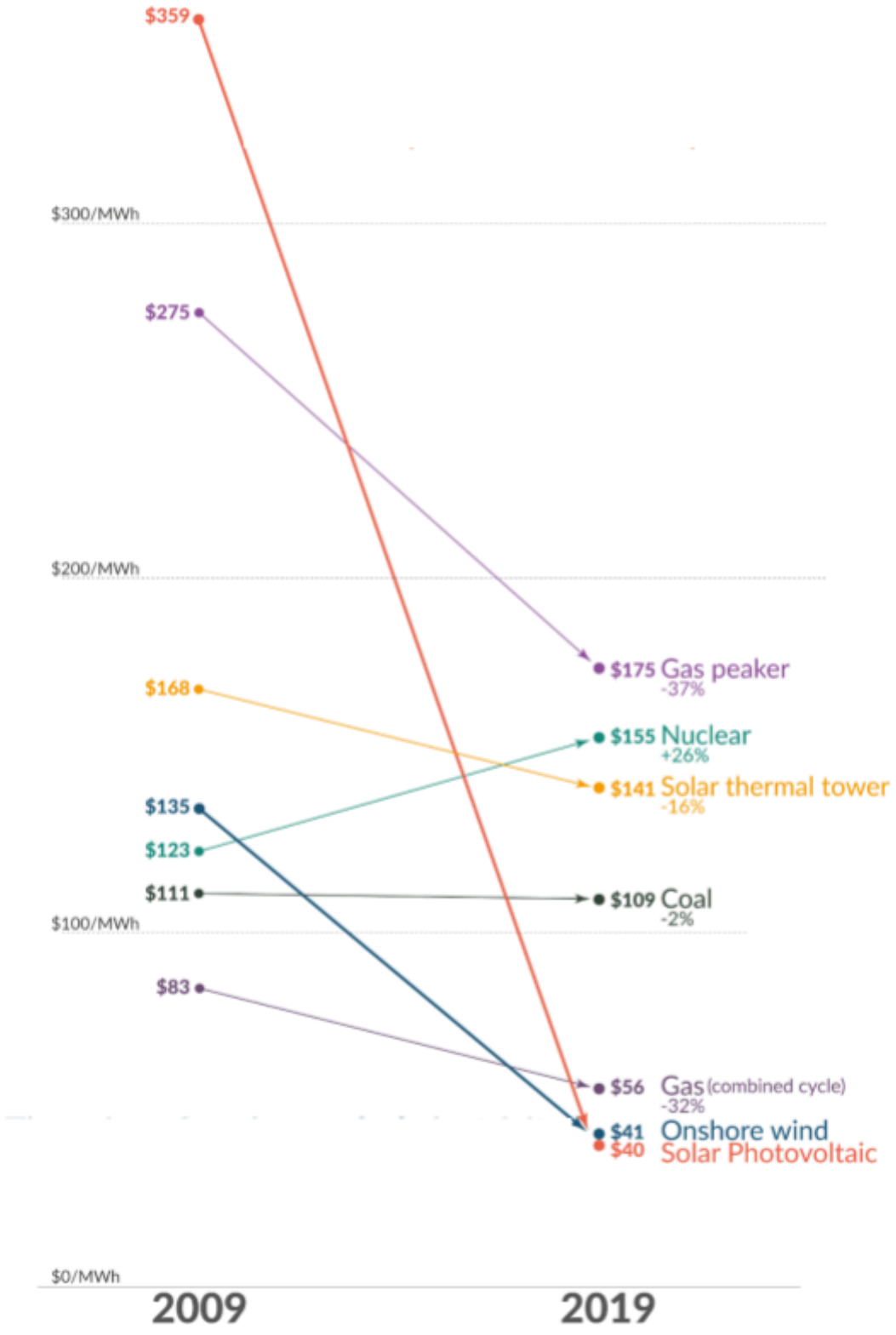
| Energy Source | Percent of Global Electricity |
|---|---|
| Coal | 36% |
| Oil | 3% |
| Natural Gas | 22% |
| Biomass | 2% |
| Hydropower | 12% |
| Wind | 7% |
| Nuclear Energy | 10% |
| Solar | 4% |

**Figure 2:**

# The price of electricity from new power plants

Our World in Data

Electricity prices are expressed in 'levelized costs of energy' (LCOE). LCOE captures the cost of building the power plant itself as well as the ongoing costs for fuel and operating the power plant over its lifetime.

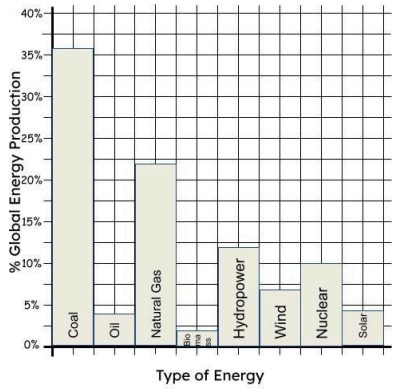



Data: Lazard Levelized Cost of Energy Analysis, Version 13.0

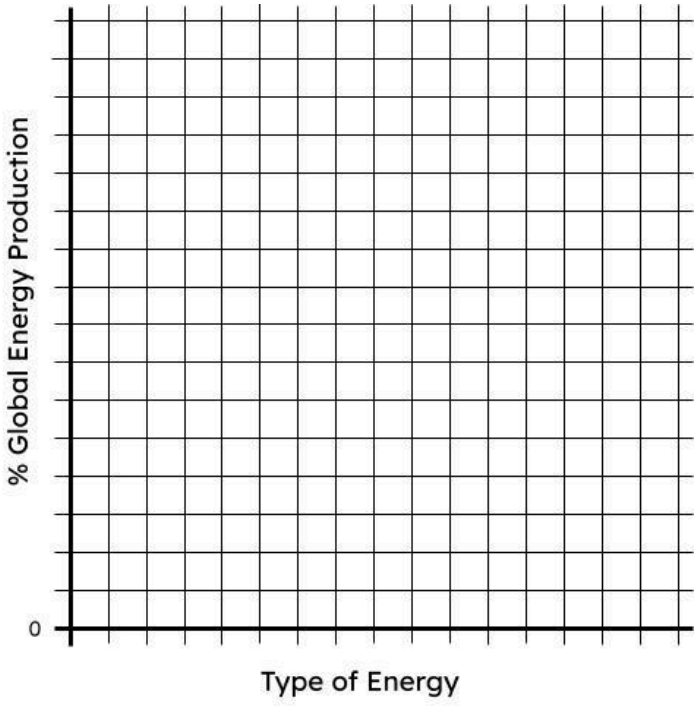
OurWorldinData.org – Research and data to make progress against the world's largest problems.

**Cluster Questions**

**Gather**:
Cluster Question #1
Question Type: Graphing
__x__ DCI: PS3.D, ETS1.A
__x__ SEP: Analyzing/ interpreting data
__x__ CCC: energy
Answer:




Question 1:
Using the data in **Table 1**, construct a bar graph showing the percentage of global energy production in 2021.




**Gather:**
Cluster Question #2
Question Type: long answer
Addresses:
__x__ DCI: PS3.D, ETS1.A
__X__ SEP: Analyzing and interpreting data
__x__ CCC: patterns, energy and matter

Answer:
A) Solar
B) Nuclear

Question 2:

Using **Figure 2**, identify:

A) The type of energy with the greatest decrease in electricity cost.

B) The type of energy with the greatest increase in electricity cost.

**Gather**:
Cluster Question #3
Question Type: multiple choice
Addresses:
__x__ DCI: PS3.D, ETS1.A

Question 3:
Based on Figure 2 and the graph you made in the previous question, does cost efficiency seem to be the most important factor in determining sources of global energy production?

a. Yes, because coal is the most cost-effective source and is one of the most used.

| | |
|---|---|
| __x__ SEP - analyzing and interpreting data<br>__x__ CCC: patterns<br>Answer:<br>**D** | b. Yes, because solar is the most cost-effective source and is one of the most used.<br>c. No, because coal is the most cost-effective source, but is one of the least used.<br>d. No, because solar is the most cost-effective source, but is one of the least used. |
| **Reason:**<br>Cluster Question #4<br>Question Type: multiple choice<br>Addresses:<br>__x__ DCI: PS3.D, ETS1.A<br>__x__ SEP: develop an argument from evidence<br>__x__ CCC: cause and effect<br>Answer:<br>**D** | Question 4:<br><br>What information from the articles above ***support*** the mining and use of tellurium?<br>A. Kennecott already mines copper and extracting tellurium from copper adds only one more step to the process.<br>B. Mining tellurium is good for the economy and security of the country.<br>C. Increased tellurium production increases our ability to create more solar panels.<br>D. All of the above |
| **Reason:**<br>Cluster Question #5<br>Question Type: multiple choice<br>Addresses:<br>__x__ DCI: PS3, ETS1.A<br>__x__ SEP: develop an argument from evidence<br>__x__ CCC: cause and effect<br>Answer:<br>**A** | Question 5:<br><br>What information from the articles above provides arguments ***against*** mining tellurium at the Kennecott mine?<br>A. The material must be shipped to Canada for processing.<br>B. Mining tellurium would increase the amount of mining and, therefore, the environmental impact of the mining.<br>C. The process used to extract the tellurium process would increase the carbon footprint by increasing the amount of $CO_2$ and other greenhouse gasses produced.<br>D. All of the above |
| **Reason and Communicate:**<br>Cluster Question #6<br>Question Type: Long answer<br>Addresses:<br>__x__ DCI: PS3.D, ETS1.A<br>__x__ SEP: developing an argument from evidence, evaluating information<br>__x__ CCC: patterns<br>Answer:<br>A. Passage 2 is most likely to contain bias, because it is written by a company trying to profit from the production of tellurium. | Question 6:<br><br>Passage 1 is taken from a local newspaper. Passage 2 is taken from Rio Tinto's company website. Passage 3 is taken from a mining technology journal.<br>A. Which would you expect to be most biased? Support your argument.<br>B. How can understanding sources of bias help consumers make better decisions? |

| | |
|---|---|
| B. Answers may vary. See below for an example: Most sources of information include some bias towards a specific opinion or outcome. This means that authors could ignore or "conveniently leave out" things that go against their agenda. It is good to have both sides of the argument because we can see the things that the other would leave out. So neither argument is totally reliable. | |
| **Communicate:**<br>Cluster Question #7<br>Question Type: Long answer<br>Addresses:<br>__x__ DCI: PS3.D, ETS1.B<br>__X__ SEP: developing an argument from evidence<br>__x__ CCC: cause and effects<br><br>Answer:<br>Student answers may vary, but may address the following:<br>● Tellurium is needed to build solar panels<br>● There are few additional environmental effects to extracting tellurium from the copper ore<br>● Solar energy is renewable<br>● There is little additional cost in extracting tellurium from the already mined copper ore.<br>● Solar energy production causes very few deaths.<br>● Solar energy is becoming cheaper to | Question 7:<br><br>Based on the information you've collected, give your opinion on whether or not making solar panels is worth the cost and possible damage that comes from mining tellurium. Be sure to address cost, environmental impacts, safety and trade-offs, etc. (Give at least two reasons and cite a specific detail from one or two of the passages to support your claim.) |

| | |
|---|---|
| produce.<br>● There is a limited supply of trace elements, such as tellurium, which we may consume too quickly.<br>● There is a $2.9 million initial investment<br>. | |
| **Communicate:**<br>Cluster Question #8<br>Question Type: Long answer<br>Addresses:<br>__x__ DCI: PS3.D, ETS1.C<br>__x__ SEP: developing an argument from evidence, planning and carrying out investigations<br>__x__ CCC: cause and effect<br>Answer:<br>Answers will vary. Students should identify what they think is the most important information that would help them make a better choice. Students should state how this new information would change their response.<br>Examples:<br>If I knew how much Tellurium a solar panel used, I could make a better decision because I would know if we actually need 20 more tons of Tellurium per year or if we have enough for solar panels already.<br><br>If I had evidence that showed that the environment was harmed more by mining Tellurium itself, I would choose to not mine Tellurium. But from the evidence, it is not clear if mining Tellurium itself adds | Question 8:<br><br>A. If you could obtain additional information, what additional information would be most important to know to help you choose whether to mine Tellurium in Utah?<br><br>B. How could this information change your response to question 7? |

| | |
|---|---|
| more pollution. If it doesn't add more pollution, I would choose to mine it. If it adds a lot of pollution, I wouldn't mine it.<br><br>If I had evidence to show how much money tellurium mining produced for the company and the state economy, it would help me make a better choice. If the mine is making significantly more than they invested, it seems worth it. If the mine will lose money mining tellurium, it doesn't seem worth mining | |

**Proficiency Scale**

**Proficient Student Explanation:**

Criteria: Students will identify criteria based on how much it costs, how much is produced, and environmental impacts, and societal impacts

Identify Trade-offs: Students identify trade-off between different sources of energy

| Level 1 - Emerging | Level 2 - Partially Proficient | Level 3 - Proficient | Level 4 - Extending |
|---|---|---|---|
| **SEP:**<br>Does not meet the minimum standard to receive a 2. | **SEP:**<br>Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.<br><br>Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system, based on empirical evidence | **SEP:**<br>Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.<br><br>Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine | **SEP:**<br>Extends beyond proficient in any way. |

| | | | |
|---|---|---|---|
| | concerning whether or not the technology meets relevant criteria and constraints. | the merits of arguments.<br><br>Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student generated evidence. | |
| **CCC:**<br>Does not meet the minimum standard to receive a 2. | **CCC:**<br>Energy cannot be created or destroyed—only moves between one place and another place, between objects or between systems. | **CCC:**<br>Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).<br><br>The transfer of energy can be tracked as energy flows through a designed or natural system.<br><br>Meeting society's energy demands often requires trade-offs. | **CCC:**<br>Extends beyond proficient in any way. |
| **DCI:**<br>Does not meet the minimum standard to receive a 2. | **DCI:**<br>The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon based organic molecules and release oxygen. | **DCI:**<br>Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.<br><br>Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. | **DCI:**<br>Extends beyond proficient in any way. |

**(Student Facing Format on following page)**

# Student Assessment

Name: _____ Date: _____

**Stimulus**

Tellurium is in high demand and is used in new solar panels. The company Rio Tinto is deciding whether to mine Tellurium at their Utah-based Kennecott mine.

**Passage 1: Taken from a newspaper article published May 11, 2022 by the news source KSL.**

*One of the rarest elements on Earth is now in the process of being recovered from Utah's Rio Tinto Kennecott copper mine as a byproduct of copper smelting.*

*That element is tellurium — which will be produced to the tune of approximately 20 tons annually — through a new $2.9 million circuit built at the Kennecott refinery. This production puts Kennecott in an exclusive group, becoming one of only two U.S. producers of tellurium, a critical mineral used in advanced thin-film photovoltaic solar panels.*

**Passage 2: Taken from the Rio Tinto website May 11, 2022.**

*Tellurium is listed as a critical mineral by the U.S. Government due to its importance to the economy and energy security.*

*Tellurium is one of ten metals and products recovered from ore extracted at Kennecott, which produces nearly 15 percent of U.S. copper with the country's lowest carbon footprint.*

*Saskia Duyvesteyn, chief adviser for copper research and development at Rio Tinto Kennecott, says "From an overall carbon footprint, if you think about it, so much of the energy comes from the mining process and the smelting process, we actually make some energy," Duyvesteyn said. "In this process, we did not add to the carbon footprint and yet we're able to produce extra copper."*

**Passage 3: Taken from *Mining Technology* journal May 12, 2022.**

*The tellurium produced will be refined by speciality semiconductors and performance materials producer 5N Plus in North America, under an agreement signed with Rio Tinto.*

*5N Plus will refine tellurium at its facility in Montreal, Canada, and primarily supply the refined tellurium to First Solar, under an existing supply contract between the two parties.*

*"Approximately 90% of the world's tellurium resource is contained in copper ore and no other metal has more critical mineral by-products than copper."*

**Figure 1:**

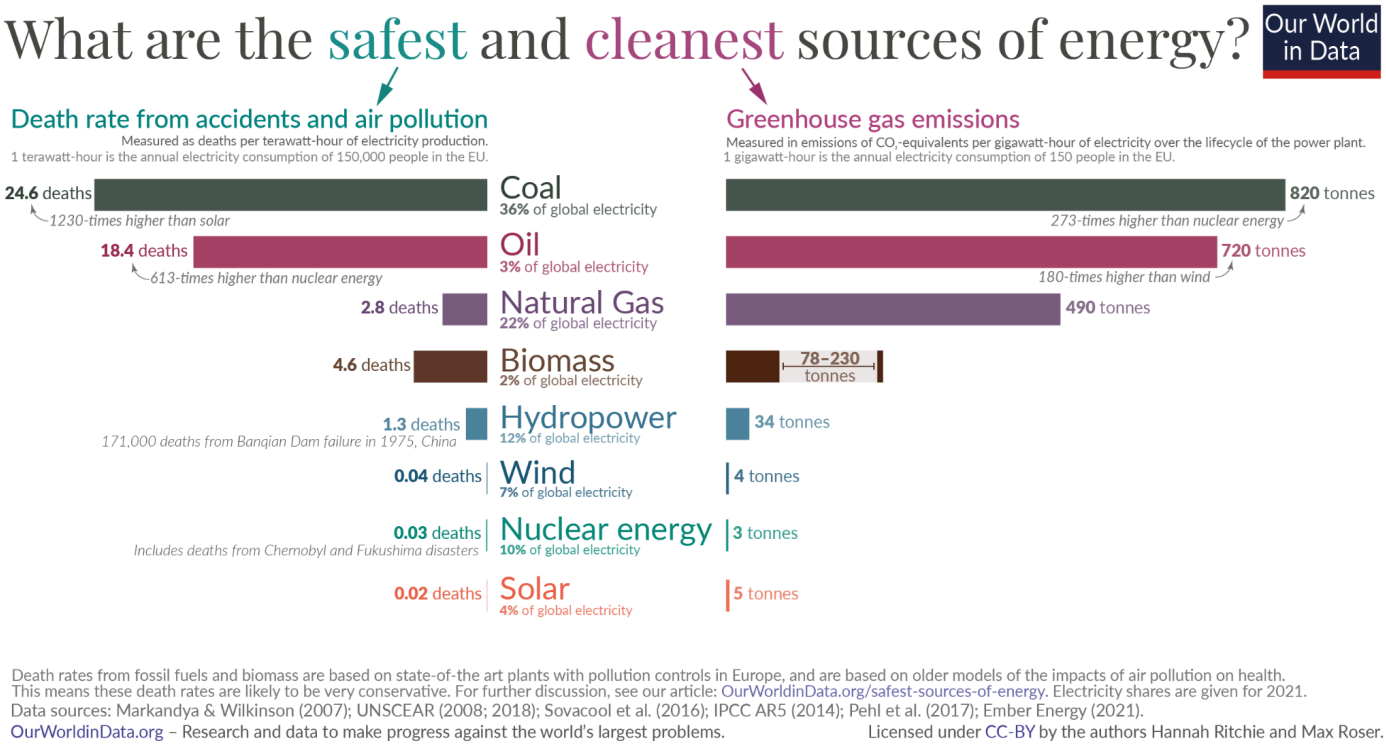
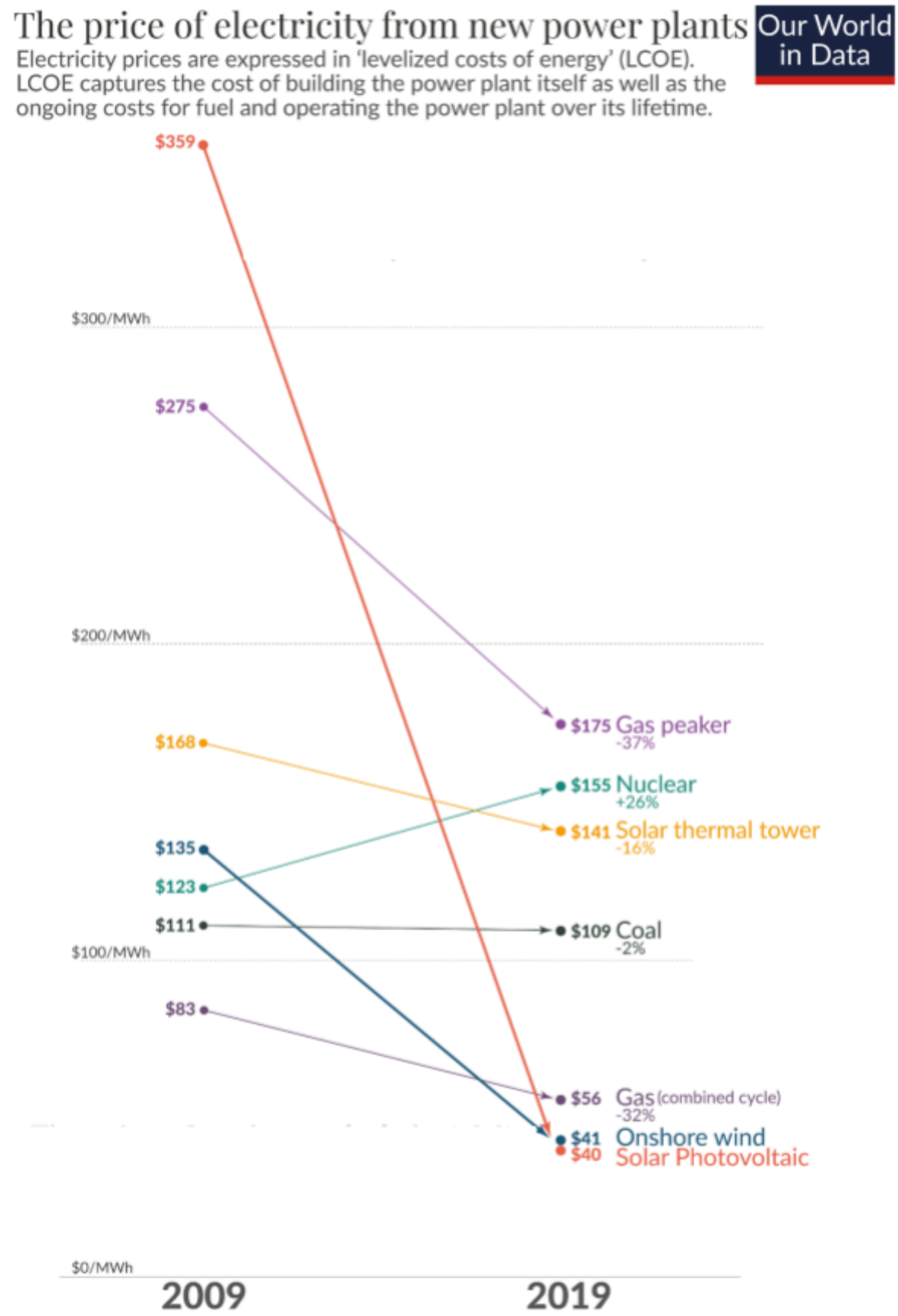



**Table 1: Energy Source and Percentage of Global Electricity taken from Figure 1**

| Energy Source | Percent of Global Electricity |
|---|---|
| Coal | 36% |
| Oil | 3% |
| Natural Gas | 22% |
| Biomass | 2% |
| Hydropower | 12% |
| Wind | 7% |
| Nuclear Energy | 10% |
| Solar | 4% |

**Figure 2:**

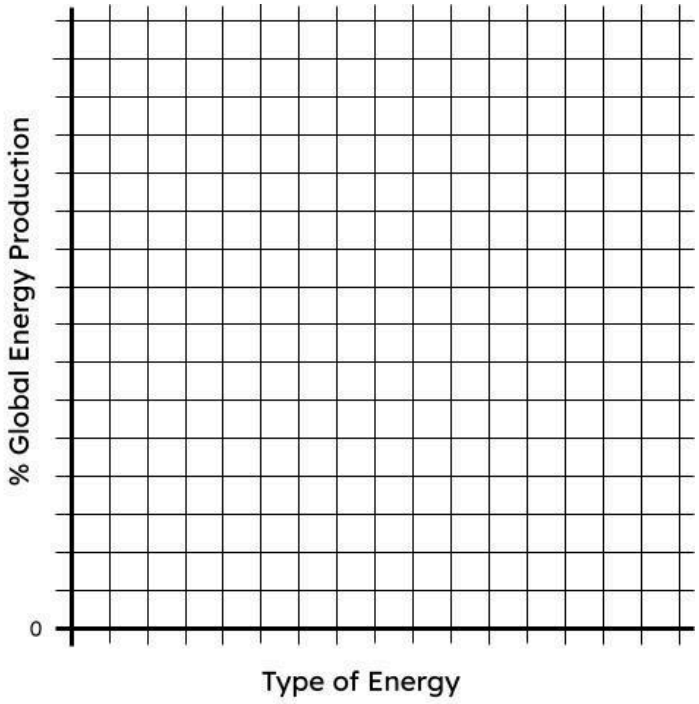

The price of electricity from new power plants
Electricity prices are expressed in 'levelized costs of energy' (LCOE).
LCOE captures the cost of building the power plant itself as well as the ongoing costs for fuel and operating the power plant over its lifetime.
Our World in Data
$359
$300/MWh
$275
$200/MWh
$175 Gas peaker -37%
$168
$155 Nuclear +26%
$141 Solar thermal tower -16%
$135
$123
$111
$109 Coal -2%
$100/MWh
$83
$56 Gas (combined cycle) -32%
$41 Onshore wind
$40 Solar Photovoltaic
$0/MWh
2009
2019
Data: Lazard Levelized Cost of Energy Analysis, Version 13.0
OurWorldinData.org – Research and data to make progress against the world's largest problems.
Licensed under CC-BY by the author Max Roser.

**Your Task**

In the questions that follow, you will develop an argument from evidence to make and defend claims regarding potential solutions to a real-world challenge. Use the information from the passage and arguments below to develop *your* argument.

**Question 1**

Using the data in **Table 1**, construct a bar graph showing the percentage of global energy production in 2021.




**Question 2**

Using **Figure 2**, identify:

A) The type of energy with the greatest decrease in electricity cost.

B) The type of energy with the greatest increase in electricity cost.

**Question 3**

Based on **Figure 2** and the graph you made in the previous question, does cost efficiency seem to be the most important factor in determining sources of global energy production?

a. Yes, because coal is the most cost-effective source and is one of the most used.
b. Yes, because solar is the most cost-effective source and is one of the most used.
c. No, because coal is the most cost-effective source, but is one of the least used.
d. No, because solar is the most cost-effective source, but is one of the least used.

**Question 4**

What information from the articles above ***support*** the mining and use of tellurium?

A. Kennecott already mines copper and extracting tellurium from copper adds only one more step to the process.
B. Mining tellurium is good for the economy and security of the country.
C. Increased tellurium production increases our ability to create more solar panels.
D. All of the above.

**Question 5**

What information from the articles above provides arguments ***against*** mining tellurium at the Kennecott mine?

A. The material must be shipped to Canada for processing.
B. Mining tellurium would increase the amount of mining and, therefore, the environmental impact of the mining.
C. The process used to extract the tellurium process would increase the carbon footprint by increasing the amount of $CO_2$ and other greenhouse gasses produced.
D. All of the above

**Question 6**

Passage 1 is taken from a local newspaper. Passage 2 is taken from Rio Tinto's company website. Passage 3 is taken from a mining technology journal.

a. Which would you expect to be most biased?

b. Support your argument. How can understanding sources of bias help consumers make better decisions?

**Question 7**

Based on the information you've collected, give your opinion on whether or not making solar panels is worth the cost and possible damage that comes from mining tellurium. Be sure to address cost, environmental impacts, safety and trade-offs, etc. (Give at least two reasons and cite a specific detail from one or two of the passages to support your claim.)

**Question 8**

a. If you could obtain additional information, what additional information would be most important to know to help you choose whether to mine Tellurium in Utah?

b. How could this information change your response to question 7?