ACTIVITY 6

Energy Storage Model

LABORATORY

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ACTIVITY SUMMARY

Students model a version of energy storage with a model "gravity battery." Then they investigate the design and role of this kind of battery, and two other kinds, in the real world. Students use credible sources to consider different types of renewable energy storage options for Vanwick. The facts gathered around energy storage inform a decision about which storage is most desirable for a Vanwick stakeholder.

ACTIVITY TYPE
LABORATORY

NUMBER OF
40–50 MINUTE
CLASS PERIODS
3

KEY CONCEPTS & PROCESS SKILLS

1. Decision analysis is the process of breaking down a decision in a way that can help the decision-maker systematically consider elements related to a choice, such as facts and values.
2. Facts support informed decision-making by leading to more accurate predictions about the likely outcomes of different choices.
3. Values affect people's decisions. There can be disagreement within a community when people hold a variety of values.
4. When gathering facts, first determine whether the source is credible before looking at the information or evidence provided by the source in more depth.
5. Making optimal decisions includes envisioning a variety of possible futures with more desirable or less desirable outcomes and identifying the choices and trade-offs needed to prepare for those futures.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:
Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. *(Science and Engineering Practice: Constructing Explanations and Designing Solutions)*

CONCEPTUAL TOOLS

WEAVING FACTS & VALUES IN DECISION-MAKING

CREDIBLE SOURCES

SCENARIO PLANNING

VOCABULARY DEVELOPMENT

energy storage
a system or device that stores potential energy when it is abundant and releases it as electrical power when it is scarce

gravitational potential energy
(assumed prior knowledge)
energy stored due to an object's mass and height

grid sharing
when two or more organizations share or buy electricity from each other through connected transmission lines (the "grid")

potential energy
(assumed prior knowledge)
energy of position or condition

TEACHER BACKGROUND INFORMATION

Gravitational Potential Energy

Gravitational potential energy is a particular type of potential energy that is a result of an object's position above the center of Earth and is given by

$$E_{GPE} = mgh$$

where E_{GPE} is the gravitational potential energy (in joules, J),
m is the mass (in kilograms, kg),
g is the acceleration of gravity (in meters per second squared, m/s^2), and
h is the height (in meters, m).

Gravitational potential energy is dependent on the object's mass, height, and the acceleration of gravity. The higher and/or more massive an object is, the greater its gravitational potential energy. Imagine dropping a 1-kilogram mass from 1 centimeter above your toes. It will hurt, but not too much. If you drop it from 1,000 centimeters above, it will impart 1,000 times more energy and could easily break a bone. Gravitational potential energy also depends on the mass of the object. When dropped from the same heights, a 10-kg mass will impart 10 times more energy than a 1-kg mass.

Kinetic Energy

Kinetic energy is the energy an object possesses because of its motion and is given by

$$E_{KE} = \frac{1}{2}mv^2$$

where E_{KE} is the kinetic energy (in joules, J),
m is the mass (in kilograms, kg), and
v is the velocity of the object (in meters per second, m/s).

Kinetic energy is dependent on the object's mass and the square of the velocity of an object. The faster it is moving and/or more massive an object is, the greater its kinetic energy. Thus, if the mass doubles, the kinetic energy doubles. However, when the speed doubles, the kinetic energy quadruples. Kinetic energy is often confused with mechanical energy. Mechanical energy is the sum of kinetic and potential energies in a mechanical system.

Electrical Energy Storage Systems

A drawback to renewable energy generation methods, such as wind and solar generation, is that they depend on specific conditions in order to generate electricity. With wind, that condition is having a constant wind speed above a certain threshold, which depends on the size of the turbine. For solar, there is a threshold intensity of light. Even hydroelectric power, which is usually very consistent, depends on having a minimum amount of water. Energy storage systems are essential to a successful renewable project to ensure that there is a reliable supply of energy. These installations store energy when it is abundant so it can be used when energy is not abundant. The controller systems for these generation-storage installations are more sophisticated than those traditionally used with fossil fuel generation because they need to quickly respond to supply and demand.

Batteries

Battery technology continues to evolve rapidly. Lithium-ion batteries are prevalent and used in small devices, vehicles, residential storage, and even in large-scale utility projects. Though the technology continues to improve and is being installed in more locations, there are downsides to lithium-battery systems, including the limited availability of lithium ore, environmental concerns about mining lithium, as well as the flammability of lithium-battery systems. There are many other battery technologies being developed, including iron-air and zinc-air flow battery systems. Many of these technologies are in the research and development stages but are promising developments for renewable energy.

Supplemental Information

The energy storage system that students model in the lab is based on a new rail-based energy system called GravityLine™ currently under construction in Nevada by Advanced Rail Energy System (ARES) North America.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 6.1A–B "Gravity Battery: Energy Diagrams"
- VISUAL AID 6.2 "Scoring Guide: Decision-Making (DM)" (OPTIONAL)
- ITEM-SPECIFIC SCORING GUIDE: Activity 6, Build Understanding item 1
- VISUAL AID 2.2 "Evaluating Online Information" (OPTIONAL)

FOR EACH GROUP OF FOUR STUDENTS

SUGGESTED MATERIALS FOR THE MODEL:

- 1.5 V–3 V MOTOR-GENERATOR, WITH MOUNT
- TURBINE HUB, OR PULLEY, ATTACHED TO THE MOTOR-GENERATOR
- RING STAND WITH CLAMP
- RAMP WITH TRACK, ABOUT 1m (3ft)
- CART
- STRING, SLIGHTLY LONGER THAN TRACK
- RULER
- SMALL MASSES, VARIOUS
- SCALE
- 9 V BATTERY (or 1.5 V D-cell battery, depending on materials)
- VOLTMETER OR MULTIMETER
- 2 WIRES WITH ALLIGATOR CLIPS
- TAPE
- SCISSORS
- VIDEO RECORDER

FOR EACH PAIR OF STUDENTS

- COMPUTER WITH INTERNET ACCESS

FOR EACH STUDENT

- STUDENT SHEET 6.1 "Design Testing Data: Gravity Battery"
- STUDENT SHEET 1.1 "Unit Concepts and Skills" (OPTIONAL)
- STUDENT SHEET 2.2 "Lateral Reading" (OPTIONAL)
- STUDENT SHEET 6.2 "Writing Frame: Decision-Making" (OPTIONAL)
- SCORING GUIDE: Decision-Making (DM) (OPTIONAL)

Determine what materials you will use in the lab and if you need to modify the procedure based on the materials you are using. You can find instructions for how to put together a model gravity battery in Appendix 3. Modify the model setup instructions for your students as needed, based on the materials you will be providing.

A suggested option is to use commercial wind turbine kits that include the motor-generator hub used in this activity. For example, Kid Wind, distributed by Vernier Science Education, carries all the basic components to build a turbine. Essential for this activity is the motor-generator and the turbine hub.

Several of the materials in this activity are also used in Activity 6: Energy Storage Model. The materials used in both activities are:

- 1.5 V–3 V motor generator
- turbine hub
- voltmeter or multimeter
- 2 wires with alligator clips
- ring stand
- scissors
- tape
- ruler

The cart must be able to hold a variety of small masses, such as pennies or fishing weights. If you do not have access to 9 V batteries, you may opt to have students reel the carts by hand while having students consider what would provide the energy for this in a real-life situation.

Note that it is easier to get readings with a longer ramp, so make the setup as large as is reasonable in your classroom.

It is recommended that students record a video of their model tests, if possible, to aid in reading the voltmeter while the cart travels. Consider recording it in slow motion, if possible.

Consider building one model gravity battery in advance for demonstration purposes. If materials are in short supply, this model could be used to gather data for the class.

If appropriate for your students, support their research into storage methods in Part C by curating some resources for pumped hydro, gravity batteries, and chemical batteries.

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in pink.

GETTING STARTED (20 MIN)

1 **Students consider the graphs in the Student Book introduction.**

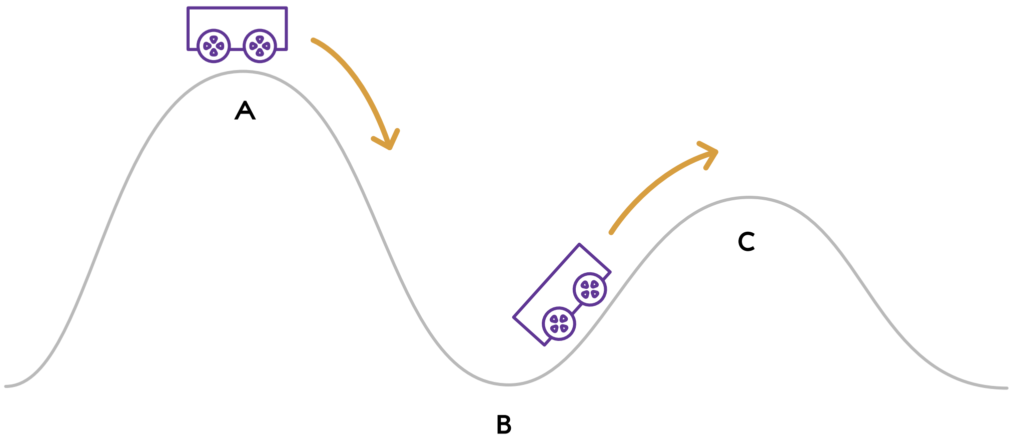
- Draw students' attention to the graphs at the start of the introduction in the Student Book. Have partners make a list of possible problems of relying on wind and solar power generation methods. Ask them to compare the trends on the graphs to their typical usage of electricity in their everyday lives. Ask, What challenges do you see with relying on wind and solar electricity generation methods? Student ideas might include:
  - Peak solar generation is in the middle of the day, which doesn't match with peak usage.
  - Peak wind generation is at night, which also doesn't match with peak usage.
  - Wind and solar generation can vary greatly based on location, weather patterns, time of year.
  - If there's not enough electricity generated, there won't be enough to meet the demand, which means that some people could be without electricity.
- Relate student's ideas about the uncertainty of not having enough power when it is needed to the previous activity when they considered possible futures with scenario planning. Considering the possible future with renewable energy makes it clear that planning for the supply–demand issue will help support a favorable outcome.
- Have students read through the scenario in Procedure Step 1 and review Vanwick's options for energy storage. Of the solutions presented, emphasize that Vanwick is looking for a solution that allows them to support the goals of Project REV, which means a solution that evens out the varying generation of renewables without depending on fossil fuels.

2 **Review the science concepts of potential energy, kinetic energy, and energy transformations.**

- Like the energy transformations identified in Activity 4, the science concepts used in this activity are those of energy transformation. All energy storage relies on transforming kinetic energy into potential energy. Energy released from storage transforms energy from potential back to kinetic. In the case of electricity, the energy can be stored in various forms, such as chemical or gravitational potential energy.

- This activity assumes that students are familiar with a basic understanding of energy transfer, transformation, and the Law of Conservation of Energy. If helpful, review the concepts of gravitational potential energy and kinetic energy in the Science Review found in the Student Book. If necessary, review the Science Review content from Activity 4.

- Formatively assess students' background on the energy transformation relevant to the gravity battery by sketching the following diagram and asking, At which point on the roller coaster is the gravitational potential energy the largest? Smallest? Likewise, ask, At which point on the roller coaster is the kinetic energy the largest? Smallest?



- Students should understand that the gravitational potential energy is largest at the top of the roller coaster, Point A, and smallest at the bottom, Point B. The kinetic energy is opposite in that it is smallest at the top of the roller coaster, Point A, and largest at the bottom, Point B. Students may know that halfway up or down the hill, or at Point C, the energy is half gravitational potential energy and half kinetic energy.

- Students should know that the Law of Conservation of Energy requires that the total energy (gravitational potential plus kinetic energy) is always the same, no matter where the cart is located.

PROCEDURE SUPPORT (70 MIN)

3 **Present the design challenge of the lab.**

- Before students begin the procedure, remind them that they will be designing a simple battery that will store energy. Their challenge is to design the system so it releases a maximum amount of energy. As in Activity 4, students will manipulate variables and measure the output voltage. Ask, What variables do you think will impact the amount of energy that can be stored and released? Students may offer many different variables in the setup but let them know that they will be testing two important ones: the height and mass of the cart.
- Compare the two design labs: In the case of Activity 4, the energy was generated by the turning turbine blades, whereas this model releases energy that was previously stored when it moves downhill. Make the distinction between Activity 4 where energy was generated and this one where energy is being stored and released. Both instances depend on a series of energy transformations. Energy is conserved in both instances.
- Let students know that they will be able to use facts they learn about energy storage in this activity to inform a decision about what is the best storage option for Vanwick from the perspective of one of the stakeholders.

4 **During the procedure, use a diagram to identify the energy transformations in the gravity battery.**

- If you constructed a demonstration model, share it with students and/or review the materials and the setup diagram in Procedure Step 2. Provide any special instructions you have regarding the setup and materials.
- In Procedure Steps 4 and 6, use Visual Aid 6.1a–b, "Gravity Battery: Energy Diagrams," to identify the energy transformations with students. The blank version, Visual Aid 6.1a is provided, in addition to the labeled one, Visual Aid 6.b, so you may work together as a class to complete it. Or you can provide a copy for students who may struggle to draw the diagram.
- Consider using the *Description of diagram* prompt under each diagram to assess a student's understanding of the science concepts. Alternatively, work on this description as a class.
- When modeling how the gravity battery works, make sure students understand that the location of the cart is at the top of the ramp when the energy has been stored and that energy is being released (i.e., electricity generated) when the cart is rolling down the ramp.
- Ask students to put the model into a real-life context. Ask, If this was scaled up and used in real life, where do you think that energy to move the mass uphill would come from? Students should be able to envision a large-scale version of the model where the energy for the uphill portion of the train comes from the electric grid. This could include nearby wind turbines or solar panels.

5 Students practice recording the gravity-battery data, using the voltmeter.

- In Procedure Steps 7–9, students test the gravity-battery system and practice video recording the voltmeter. If necessary, provide instructions on how to properly set up and read the voltmeter and record it in slow motion (see Teacher Background Information). If students are not able to record the voltmeter, then designate one student in each group whose job is to specifically watch the voltmeter during the trial.

Sample Student Response, Procedure Step 8

GRAVITY-BATTERY DATA

TRIAL	MAXIMUM VOLTAGE (V)
1	*1.30 V*
2	*1.71 V*
3	*1.30 V*
average	*1.63 V*

- Once students have gathered their data and found the average maximum voltage, ask, Why is getting the average of the voltages better than using one reading? Depending on student background, answers will vary. Most students will recognize that averaging multiple trials can balance out the variability they saw over the trials. Taking an average of several trials gives a more accurate result.

TEACHER'S NOTE: If students have completed the previous unit on correlation, Evidence & Correlation, they may recognize the importance of averaging data. Connect the ideas from this activity to the one in the previous unit where averaging across more data is used to reduce random error.

6 Challenge groups to design the gravity battery to produce the highest voltage.

- In Part B of the activity, students maximize the amount of voltage produced by their models by experimenting with the cart mass and ramp height. Remind students that they did something similar in Activity 4 with investigating the variables that increased the voltage output of the model wind turbine. Review the concept of a variable and how it is important to change only one variable at a time when you are conducting an experiment. Isolating one variable at a time allows you to better see how changes in your design affect the results.
- Distribute Student Sheet 6.1, "Design Testing Data: Gravity Battery," for students to record their data and average the voltages from their trials. Provide the second page of the student sheet to those students who perform more than three design iterations. Students may find that there is more than one configuration of mass and height that gives similar results. This makes sense since gravitational potential energy is directly proportional to both mass and height. A Sample Student Response is found at the end of this activity and includes a variety of combinations.

- As with Activity 4, a negative voltage does not have meaning for this laboratory. It indicates how the voltmeter is connected. If the peak voltage change is negative, switch the two wires on the voltmeter or tell students to ignore it.

- At the end of Part B, collect and discuss the lab results as a whole class. Consider writing the class data on the board for further discussion and comparing results. Ask groups to share their max voltage, mass, and heights. Students' data should show that changing either mass or height will increase the output. Due to friction on the ramp, it is likely that they saw a bigger effect with height.

- Based on what they learned from the model, ask, What characteristics would a real-life gravity battery for Vanwick have? Students should infer that it would need a fair amount of space to build carts and tracks. It would need to have much more height and much more mass based on how little voltage their model released. The hill should not be so tall or steep that the carts roll out of control at the bottom. Since it would be hard to change the height, perhaps there would be some way that the mass could be changed.

7 **Guide student research on various kinds of energy storage.**

- In Part C, students investigate different battery technologies in addition to the one they experimented with in Parts A and B. Each student investigates one of the technologies and reports to the larger group. If you prefer to increase access for students during the research, use a "jigsaw" approach. Have students investigate one topic with their group and then reassemble the groups so each member goes to a different group to provide expertise on their group's research.

- In Procedure Step 16, the fourth technology shown in the table is left open for either you or students to choose. There are many types of energy storage for renewable systems to choose from. Systems that are simple to understand and explain the energy transformations include mechanical systems, such as compressed air and flywheel systems. There are also thermal batteries, hydrogen storage, and many kinds of electrochemical batteries. One interesting storage type you may want to offer is the emerging use of iron-air batteries.

- The following resources provide some examples of where the three provided methods are installed. Depending on your students' needs, it may be helpful to scaffold their research by providing the following references.

Rail-Energy Storage

- A New Kind of Renewable Energy Storage. *(YouTube)*
- Energy Storage Hits the Rails Out West. *(Scientific American)*
- The Train Goes Up, the Train Goes Down: A Simple New Way to Store Energy. *(Vox)*

Pumped Hydro Storage

- The Ludington plant features one of the "world's largest batteries." *(Detroit News)*
- Largest Pumped-Hydro Facility in World Turns on in China. *(CleanTechnica)*
- Pumped Storage Hydropower. *(United States Department of Energy)*

Large-Scale Lithium-Ion

- Creating Our Clean Energy Future—PG&E Commissions its Moss Landing Elkhorn Battery. *(Youtube)*
- Grid-Scale Battery Storage: Frequently Asked Questions. (*National Renewable Energy Laboratory)*
- Victorian Big Battery: Australia's Biggest Battery Storage System at 450MWh Is online. *(Energy Storage News)*

Other Types of Grid-Level Energy Storage

- Electricity Storage. *(United States Environmental Protection Agency)*
- Energy Storage in the UK, An Overview. *(Renewable Energy Association)*

• Remind students that they should use credible sources anytime they conduct web research. Review how to check for credible sources, using lateral reading and checking for expertise. You may wish to revisit Visual Aid 2.2, "Evaluating Online Information," with students. If you are showing the videos listed, consider using them to model the process again.

• Be clear about the expectations for the level of research for your students. This can vary depending on the abilities and interests of your students. In Build Understanding item 1, students are provided with facts about storage disadvantages in case they did not discover them during the procedure.

• Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by adding terms to the word wall. For this activity, add the terms that relate to the science content such as *energy transformation, kinetic energy* and *potential energy* (if they weren't added in Activity 4), *energy storage,* and *grid sharing.* Provide additional examples for each term as needed.

SYNTHESIS (30 MIN)

8 **Lead a discussion about the trade-offs of different storage options.**

• Have groups share the advantages and disadvantages for each storage option discussed in their groups. When students choose a storage system on behalf of Vanwick residents in Procedure Step 17, it will help them identify the advantages and disadvantages of each choice.

• Review the concept of trade-offs introduced in the previous activity. Review the definition: when a desirable outcome is given up to gain another desired outcome.

- In Procedure Step 17, remind students of the most common values from the survey in Activity 3. Most likely these were retaining natural views, reducing greenhouse gas emissions, and maintaining jobs. Students need to make a decision based on those values and the relevant facts they found in the activity.

Sample Student Response, Procedure Step 17

Because the most common value for Vanwickians is maintaining views, my choice is the lithium-ion battery storage. This is because this storage system is the smallest one and can be put in many locations. It can be placed out of sight of the residents or easily screened by trees. The trade-off of this choice is that it gives up a low environmental impact compared to other choices. It has the disadvantage of involving a lot of mining for the natural resources for the batteries, which gives off a lot of greenhouse gases to mine and destroys the habitat.

9 **Build Understanding item 1 can be assessed using the Decision-Making Scoring Guide.**

- Remind students of the Decision-Making Scoring Guide. You may wish to project Visual Aid 6.1, "Scoring Guide: Decision-Making (DM)," for your students to review each level and clarify your expectations.
- Do not share the item-specific version of the Scoring Guide (Item-Specific Scoring Guide: Activity 6, Build Understanding item 1) with students as it provides specific information on how to respond to the question prompt.
- For students who need support organizing and writing their responses, you may wish to provide optional Student Sheet 6.2, "Writing Frame: Decision-Making," to compose their responses. Students could also use Student Sheet 6.2 only as a reference or as a checklist as they write their responses. A sample student response for this student sheet is shown at the end of this activity. For more information on a Writing Frame, see Appendix 1: Literacy Strategies.
- Remind students that you expect to see them demonstrate growth in their understanding and explanation of decision-making, and they may want to review their responses to the assessment in Activity 4 (Build Understanding item 1). Depending on your students, you may want to have them provide feedback on one another's work for revision prior to turning in the work to you for scoring. Alternatively, consider having students turn in a rough draft for feedback and revision.
- Sample responses for Levels 1–4 are provided in the Build Understanding section that follows. Review these responses to get an idea of what is expected for each level, alongside the Item-Specific Scoring Guide. See Appendix 2: Assessment Resource at the end of the Teacher's Guide for more guidance and information on using the Scoring Guides and assessment system with your students.

10 Relate the activity to scenario planning.

- Discuss Build Understanding item 3. Students are presented with uncertainty in the future about wind levels. Remind students that this question relates to what they did in the last activity when they imagined the future by using uncertain factors (in that case, wind levels). Ask students to apply what they learned in the last activity to the decisions they make now.
- You may wish to revisit Student Sheet 1.1, "Unit Concepts and Skills," to help students formally organize the ideas introduced in the unit so far. Students can add the headings of "Expertise" and/or "Scenario Planning" into the organizer and add examples from their classroom experiences in Activities 4–6. See the end of Activity 1 in the Teacher's Edition for a sample student response.
- Complete the activity by evaluating if your students are able to identify the essential ideas of the activity related to the key concepts and process skills. Emphasize that in this activity, the facts that students gained supported the decision-making they made from identified values.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

① **DM Assessment**

Angelo Obrero is a resident of Vanwick. He supports Project REV because it supports one of his most important values: to preserve the natural world. When researching the storage systems, he learned that the different energy-storage systems have the following disadvantages:

- Building a pumped hydro-gravity system will flood an entire ecosystem, permanently changing it.
- Making chemical batteries takes a lot of energy and resource mining, which can cause significant environmental damage.
- A rail-energy gravity battery will take up some land that would otherwise remain in its natural state.

Review these facts and the ones you gathered in Part B about energy-storage systems and consider how they relate to Angelo's value. Based on this, which energy-storage system do you think Angelo would recommend to Vanwick's City Council to be included in Project REV? Explain your decision, including the following:

- relevant facts and stakeholder values and how they affected your decision
- predicted outcome(s) of your decision
- any trade-offs involved in your decision

Level 4 response

I think that Angelo will probably recommend the rail-energy gravity battery to the Vanwick City Council for Project REV. Even though the rail-gravity battery will take up some land, the pumped hydro-gravity system would flood an entire ecosystem and permanently change it. Making chemical batteries such as a lithium-battery system would require lots of energy and mining natural resources. Because the value of preserving the natural world is important to Angelo, I think he would choose the option that changes the natural world the least. Mining and flooding both change the environment significantly, so the rail battery is the best option, considering Angelo's value. If the City Council agrees with Angelo, the likely outcome is that they will use up some land for the rail-battery system but will be working toward fulfilling the goals of Project REV. An important trade-off is that there are not many rail-gravity systems built yet, so it's possible there will be problems with the system in the future because there might be challenges that aren't known yet. They would also be using land that would otherwise be left in its natural state.

Level 3 response

I think that Angelo will probably recommend the rail-energy gravity battery to the Vanwick City Council. Even though the rail-gravity battery will take up some land, the other systems do more damage to the land. Since Angelo values preserving the natural world, he would want to do less damage to it. If the City Council agrees with Angelo, a likely outcome will be some land use. One trade-off is that not many of these systems have been built yet.

Level 2 response

I think that Angelo will probably recommend the rail-energy gravity battery, because it doesn't damage the natural land too much. So, they would use some land, but that's a trade-off.

Level 1 response

I think that Angelo will recommend the rail-energy gravity battery. Batteries like this are always the best choice because they don't change the environment.

② **Imagine that, in the previous question, Angelo Obrero also has prioritized the value of not using a lot of land for the storage system. Does this additional value change your decision about what storage to recommend?**

These are conflicting values because taking up a small space would point to lithium storage, which conflicts with the value of preserving the environment. Would need to know priorities of the values, or the weighted values, to make a decision.

③ **Recent data has shown that wind patterns are changing in many regions on Earth, with some places experiencing "wind droughts," or periods of time with reduced wind speeds. By the year 2100, global wind speeds could fall by up to 10%. Given this possible future, what steps should Vanwick take now to ensure that it will be able to meet its power needs in the future?**

Vanwick needs to take into consideration that there is uncertainty about how much wind there will be in the future. If there is less wind in the future, as predicted, they could plan for that. They could use a different source other than wind power, or they could add extra turbines to make up for the drop in wind speed. Deciding to have extra generation and types of storage would be good planning for different possible futures.

CONNECTIONS TO EVERYDAY LIFE

4. **Your parents are deciding whether they should install solar panels at your home or buy a used electric vehicle. How would you advise them about how to make this decision?**

   I need to know more about their values before deciding on what types of facts they would need to help them decide. Is cost the biggest factor? Do they care more about greenhouse gas emissions? After I know their values, I can help them compare how much emissions are saved with each option and how much each option costs to see which option fits better with their values.

5. **Your friend tells you that buying new clothes from a regular store uses less energy than buying used clothes from a thrift (secondhand) store. She cites that a popular environmental influencer posted online that new clothes are now made in a more energy-efficient way than they used to be.**

   a. **How would you find a credible source to support or refute your friend's claim?**

      I would start by doing lateral reading to find out more about the environmental influencer she is citing. I could do a search and see what type of experience and education that person has, and if they have a reputation for posting biased information or untrustworthy information in the past.

   b. **What type of expert would you look for as a source to support or refute your friend's claim?**

      I could look for experts related to sustainability or clothing production. There are probably scientists studying the environmental effects of clothing production, so I can see if they say the same things.

REFERENCES

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STUDENT SHEET 6.1 | DESIGN TESTING DATA: GRAVITY BATTERY | NAME

DESIGN ITERATION NUMBER ______

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1				
2				
3				
Average				

DESIGN ITERATION NUMBER ______

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1				
2				
3				
Average				

DESIGN ITERATION NUMBER ______

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1				
2				
3				
Average				

STUDENT SHEET 6.1 | DESIGN TESTING DATA: GRAVITY BATTERY | NAME

CONTINUED

DESIGN ITERATION NUMBER ______

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1				
2				
3				
Average				

DESIGN ITERATION NUMBER ______

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1				
2				
3				
Average				

DESIGN ITERATION NUMBER ______

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1				
2				
3				
Average				

STUDENT SHEET 6.1 | DESIGN TESTING DATA: GRAVITY BATTERY | NAME *SAMPLE STUDENT RESPONSE*

DESIGN ITERATION NUMBER *1*

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1	*54*	*19*	*1.30*	*Cart rolls slowly downhill.*
2	*54*	*19*	*1.71*	
3	*54*	*19*	*1.87*	
Average			*1.63*	

DESIGN ITERATION NUMBER *2*

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1	*108*	*19*	*2.55*	*Cart rolls a little faster than the last design.*
2	*108*	*19*	*2.27*	
3	*108*	*19*	*2.37*	
Average			*2.40*	

DESIGN ITERATION NUMBER *3*

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1	*201*	*19*	*2.85*	*Cart rolls the fastest yet.*
2	*201*	*19*	*2.86*	
3	*201*	*19*	*2.73*	
Average			*2.81*	

CONTINUED

DESIGN ITERATION NUMBER 4

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1	54	38	3.20	Cart rolls faster compared to same weight at 15 cm height.
2	54	38	2.39	
3	54	38	2.91	
Average			2.83	

DESIGN ITERATION NUMBER 5

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1	108	38	3.56	Cart rolls even faster and jolts the string when it reaches the end.
2	108	38	3.64	
3	108	38	2.90	
Average			3.37	

DESIGN ITERATION NUMBER 6

TRIAL	MASS (g), CART + LOAD	HEIGHT (cm)	VOLTAGE (V)	OBSERVATIONS
1	201	38	3.51	Cart rolls the fastest, and the weights go flying unless you stop it at the end. Voltage was > 4V once!
2	201	38	4.23	
3	201	38	3.54	
Average			3.73	

STUDENT SHEET 6.2 | WRITING FRAME: DECISION-MAKING | NAME

I/we/they have decided

The value(s) that I/we/they are weighting most heavily is

One fact related to the value is

A second fact related to the value is

Together, these facts and values affect the decision because

The likely outcome of this decision is

(OPTIONAL) **The trade-offs of this decision were**

(OPTIONAL) **This decision involved compromising about**

STUDENT SHEET 6.2 | WRITING FRAME: DECISION-MAKING | NAME *SAMPLE STUDENT RESPONSE*

I/we/they have decided

that Vanwick should not use only wind turbines.

The value(s) that I/we/they are weighting most heavily is

that Vanwick residents don't want to see or hear the renewable energy sources.

One fact related to the value is

that they need 63 wind turbines to get enough power.

A second fact related to the value is

that they have space to build this many if they build them near homes, the school, and the park.

Together, these facts and values affect the decision because

it means that they can't build all the wind turbines they would need without building them where people would see or hear them.

The likely outcome of this decision is

that they will need another source of renewable energy.

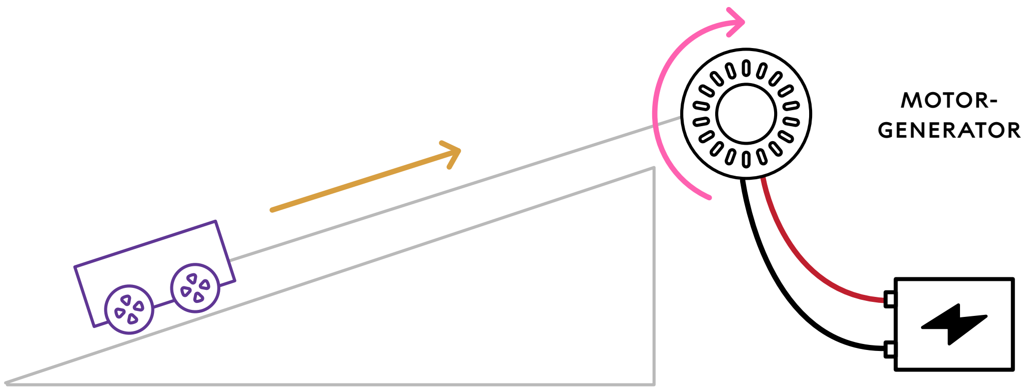
(OPTIONAL) **The trade-offs of this decision were**

N/A

(OPTIONAL) **This decision involved compromising about**

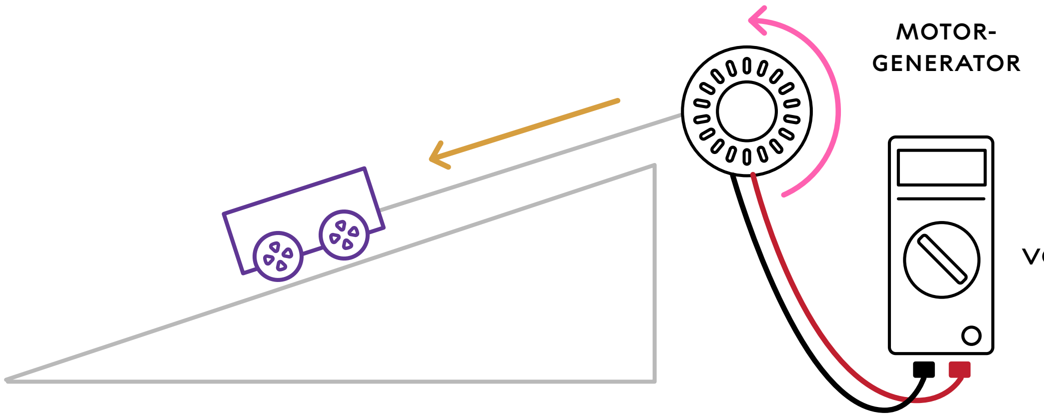
N/A

STORING ENERGY



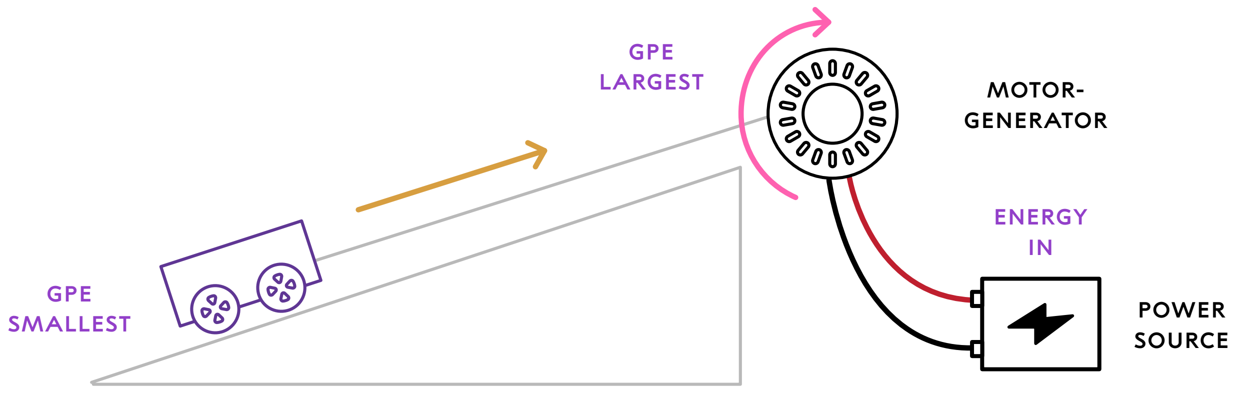
Description of Diagram

RELEASING ENERGY



Description of Diagram

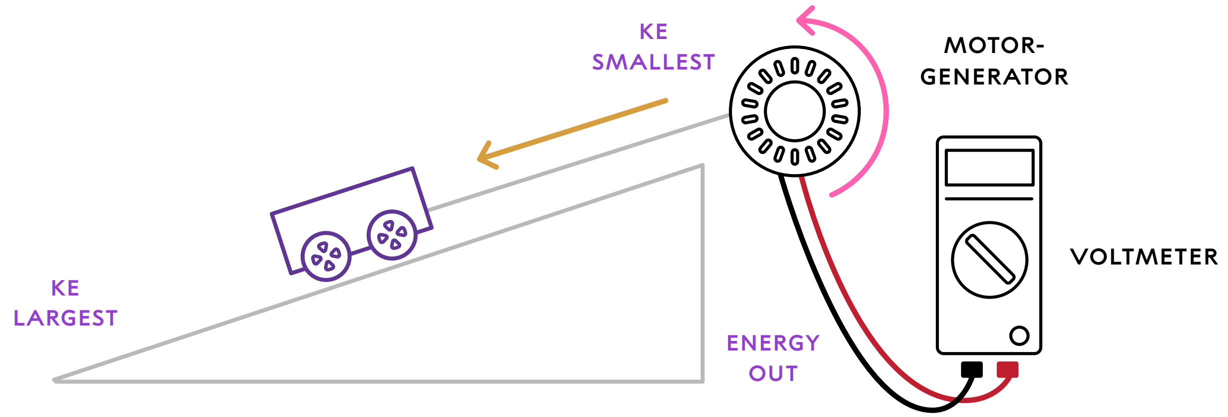
STORING ENERGY



Description of Diagram

The electrical energy from the battery transforms into kinetic energy when it turns the motor-generator hub. Lifting the cart up the hill transforms the kinetic energy into gravitational potential energy.

RELEASING ENERGY



Description of Diagram

The gravitational potential energy of the cart at the top of the hill is transformed into kinetic energy when it rolls downhill. The motor-generator hub transforms that energy of motion into electrical energy.

VISUAL AID 6.2 | SCORING GUIDE: DECISION-MAKING (DM)

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students are explaining a decision (sometimes in the form of a recommendation) that incorporates relevant facts and values and predicts possible outcomes.

WHAT TO LOOK FOR:

- Response incorporates and explains the effects of relevant facts and stakeholder values on the decision.
- Response identifies trade-offs (if appropriate).
- Response describes any compromises made (if appropriate).

LEVEL	GENERAL DESCRIPTION
Level 4 **Complete and correct**	The student explains a decision made from two or more options that incorporates: • one or more relevant stakeholder values. • the facts associated with those values. • how the facts and values affected the decision. • predicted outcome(s) supported by the relevant facts. • any trade-offs made as a result of weighing the relevant facts and values (if appropriate). • any compromise made by stakeholders (if appropriate).
Level 3 **Almost there**	The student explains a decision made from two or more options that incorporates most of the following, BUT one or more may be insufficiently described: • one or more relevant stakeholder values • the facts associated with those values • how the facts and values affected the decision • predicted outcome(s) supported by the relevant facts • any trade-offs made as a result of weighing the relevant facts and values (if appropriate) • any compromise made by stakeholders (if appropriate)

LEVEL	GENERAL DESCRIPTION
Level 2 **On the way**	The student provides a clear and relevant decision, BUT the explanation of supporting facts and values is incomplete.
Level 1 **Getting started**	The student provides a clear and relevant decision BUT provides inaccurate or unrelated facts, unrelated values, and/or an illogical explanation of the decision.
Level 0 **Missing or off task**	Student response is missing, illegible, or irrelevant.
X	The student had no opportunity to respond.

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students are explaining a decision (sometimes in the form of a recommendation) that incorporates relevant facts and values and predicts possible outcomes.

WHAT TO LOOK FOR:

- Response incorporates and explains the effects of relevant facts and stakeholder values on the decision.
- Response identifies trade-offs (if appropriate).
- Response describes any compromises made (if appropriate).

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 4 **Complete and correct**	The student explains a decision made from two or more options that incorporates: • one or more relevant stakeholder values. • the facts associated with those values. • how the facts and values affected the decision. • predicted outcome(s) supported by the relevant facts. • any trade-offs made as a result of weighing the relevant facts and values (if appropriate). • any compromise made by stakeholders (if appropriate).	**The student identifies which storage system would be recommended and explains their decision, incorporating the following:** • 2–3 relevant facts (gravity battery takes land, pumped hydro floods/permanently changes ecosystem, chemical batteries use energy/require mined resources) • stakeholder value of not wanting to change the natural world • why/how the chosen option addresses stakeholder values • 1–2 trade-off(s) based on chosen storage system • 1–2 outcome(s) based on chosen storage system **However, additional relevant facts, values, and outcomes may be considered.**

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 3 **Almost there**	The student explains a decision made from two or more options that incorporates most of the following, BUT one or more may be insufficiently described: • one or more relevant stakeholder values • the facts associated with those values • how the facts and values affected the decision • predicted outcome(s) supported by the relevant facts • any trade-offs made as a result of weighing the relevant facts and values (if appropriate) • any compromise made by stakeholders (if appropriate)	**The student identifies which storage system would be recommended and explains their decision, incorporating most of the following, BUT one or more may be insufficiently described:** • 2–3 relevant facts (gravity battery takes land, pumped hydro floods/permanently changes ecosystem, chemical batteries use energy/require mined resources) • stakeholder value of not wanting to change the natural world • why/how the chosen option addresses stakeholder values based on relevant facts • 1–2 trade-off(s) based on chosen storage system • 1–2 outcome(s) based on chosen storage system **However, additional relevant facts, values, outcomes, and trade-offs may be considered.**

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 2 **On the way**	The student provides a clear and relevant decision, BUT the explanation of supporting facts and values is incomplete.	The student identifies which storage system would be recommended, BUT the explanation of supporting facts and values is incomplete (e.g., only one fact, not including values, not stating possible outcomes).
Level 1 **Getting started**	The student provides a clear and relevant decision BUT provides inaccurate or unrelated facts, unrelated values, and/or an illogical explanation of the decision.	The student identifies which storage system would be recommended BUT provides inaccurate or unrelated facts, unrelated values, and/or an illogical explanation of the decision.
Level 0 **Missing or off task**	Student response is missing, illegible, or irrelevant.	
X	The student had no opportunity to respond.	