ACTIVITY 6

Energy Storage Model

LABORATORY

The upper reservoir of the Markersbach pumped hydro storage in Saxony, Germany.

6: ENERGY STORAGE MODEL

GUIDING QUESTION

How can understanding an energy storage model help make a decision about using energy storage in a community?

INTRODUCTION

One of the challenges of some renewable electrical power generation methods is that there are times when the sources cannot meet the demand. For example, solar panels only work when the Sun is shining, and wind turbines only spin when there is wind. For these electrical power generation methods, there needs to be a supplementary source of electrical power when generation is lower than demand or not available. One solution is to remain connected to fossil fuel systems for as long as fossil fuels are available. A second solution is to share electrical power among communities. This approach is called grid sharing, which is when two or more organizations share or buy electricity from each other through connected transmission lines (the "grid"). This solution is common, but it is not perfect because up to 5% of energy is lost during transmission. A third solution is to invest in an energy storage system. Energy storage is a system or device that stores potential energy when it is abundant and releases it as electrical power when it is scarce. There are various options for storing energy, such as battery systems, pumped water systems, or mechanical systems. Like electrical generation, energy storage depends on energy transformations.

In this activity, you'll model one renewable method of energy storage. Then you'll learn about real-world energy storage systems and gather facts to help with decision analysis for Vanwick's decision about the energy storage systems.

CONCEPTUAL TOOLS

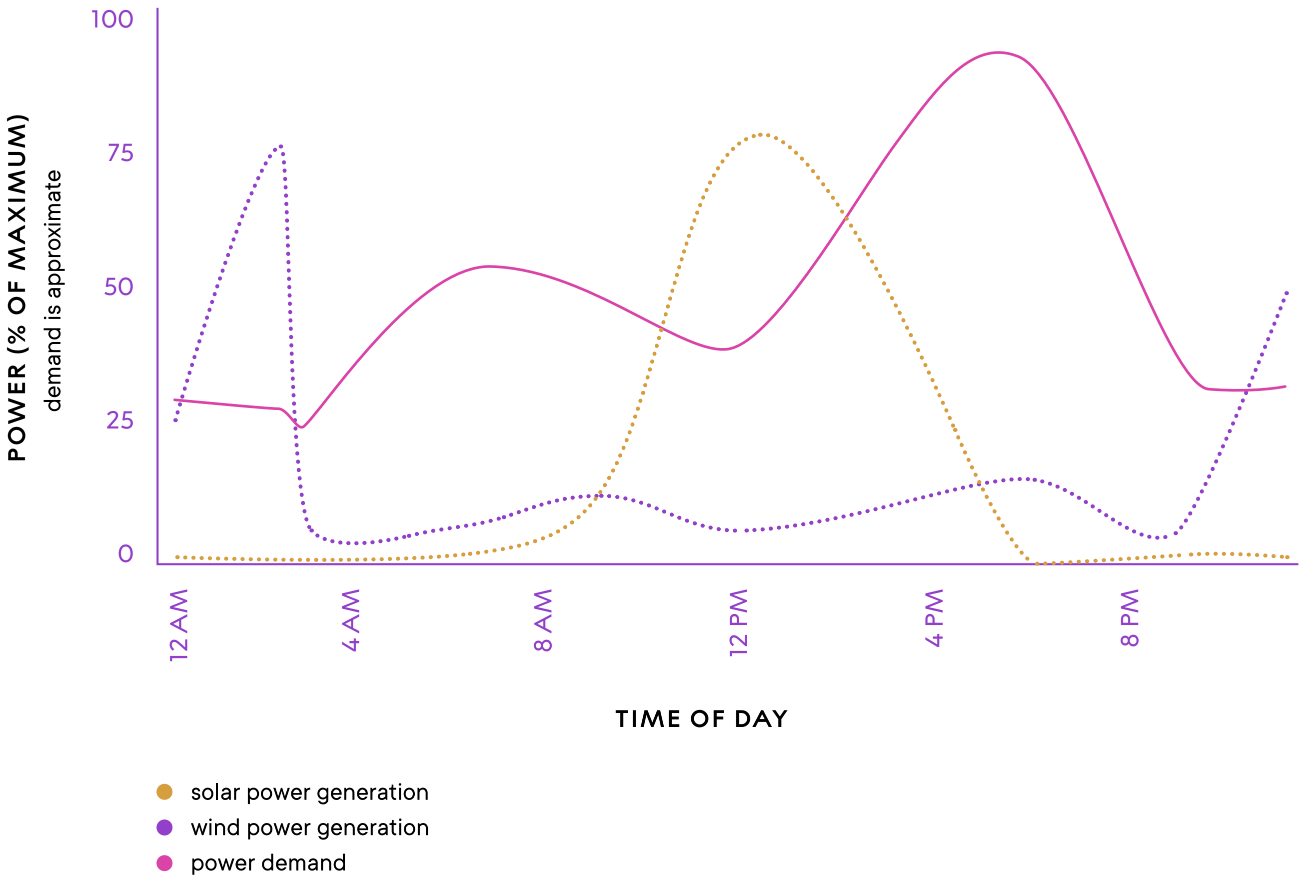
WEAVING FACTS & VALUES IN DECISION-MAKING

CREDIBLE SOURCES

SCENARIO PLANNING

FIGURE 6.1
Patterns of renewable generation and power demand

The graph shows an example of typical power-generation patterns from solar and wind, along with power demand.



MATERIALS LIST

FOR EACH GROUP OF FOUR STUDENTS

Components needed to build a model energy storage system:

- 1.5V–3V MOTOR-GENERATOR WITH MOUNT
- TURBINE HUB OR PULLEY
- RING STAND WITH CLAMP
- RAMP WITH TRACK, about 1 m (3 ft)
- CART
- STRING, slightly longer than track
- RULER
- SMALL MASSES
- SCALE
- 9V OR 1.5V BATTERY
- VOLTMETER
- 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"

PROCEDURE

PART A: MODELING A GRAVITY BATTERY

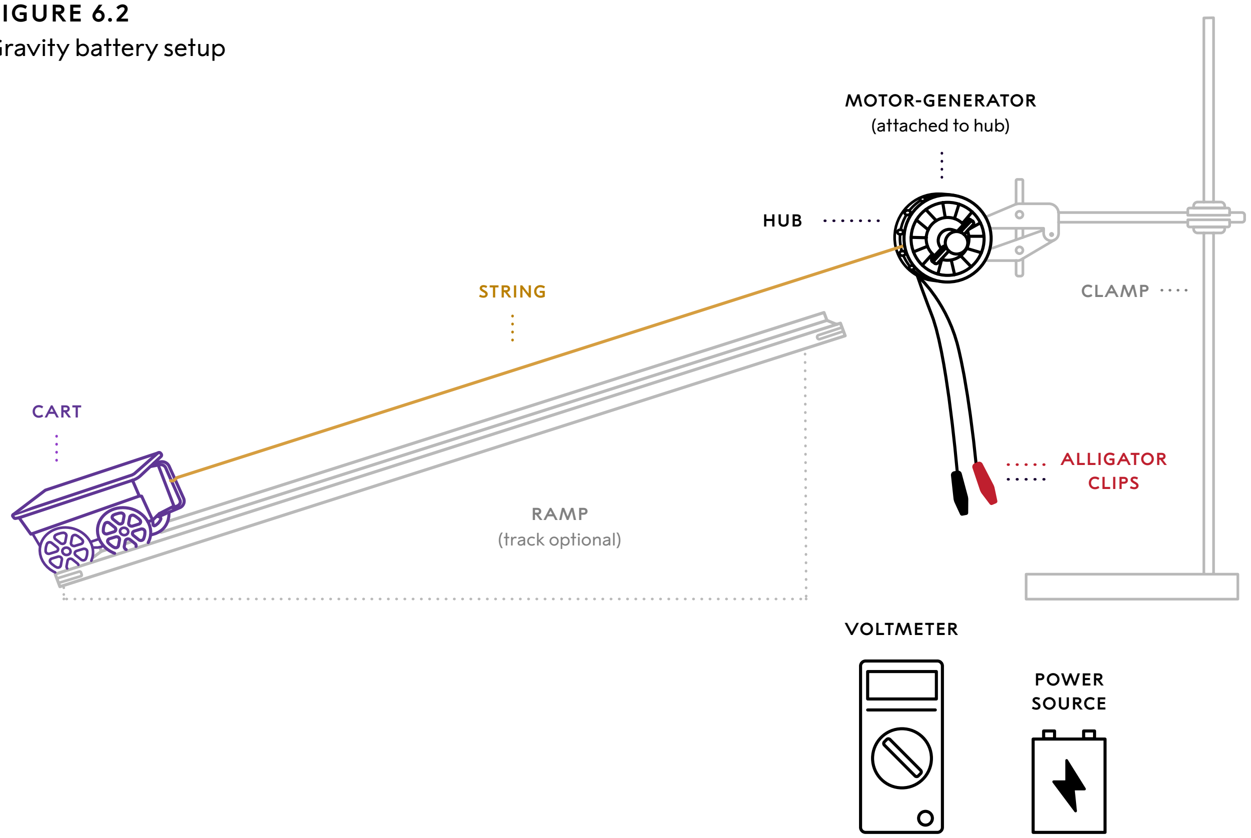
1. With your group, read the following scenario.

   Because Vanwick lacks robust transmission lines to other communities, it is not in a position to buy electricity from another location or grid share when demand increases. Even if they could, the town prefers not to buy electricity from neighboring communities as the generation would be dependent on fossil fuels. Instead, Vanwick is looking at ways to store energy for use at a later time. A local company has submitted a proposal to build an energy storage system that has a low environmental impact. Instead of using mineral-intense chemical batteries, the storage system will use some land around Vanwick to build "gravity batteries," train-like devices that are moved by energy and gravity.

2. Follow your teacher's instructions to set up the model gravity battery as shown in Figure 6.2. Make sure your ramp is tall enough (inclined) so the cart can roll down on its own. Your setup may vary from the one shown, depending on the materials your teacher provides.

> If you need to review the concept of energy transformations, you will find a Science Review at the end of this activity.

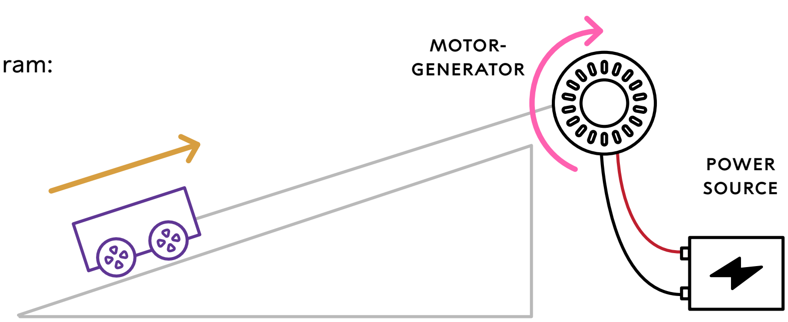
FIGURE 6.2
Gravity battery setup



3 Connect the power source to the motor-generator wires to model the charging phase of the model gravity battery. In this phase, the cart moves up the ramp to store energy. Check that the hub is aligned straight over the ramp so the string will wind smoothly during the test.

4 With the class, work together to identify, in Figure 6.3, all the energy transformations from Step 3. Discuss how the cart waiting at the top of the hill is similar to a charged battery. Copy the diagram into your science notebook, label it, and record a sentence that explains what happened in Step 3 in terms of energy transformations.

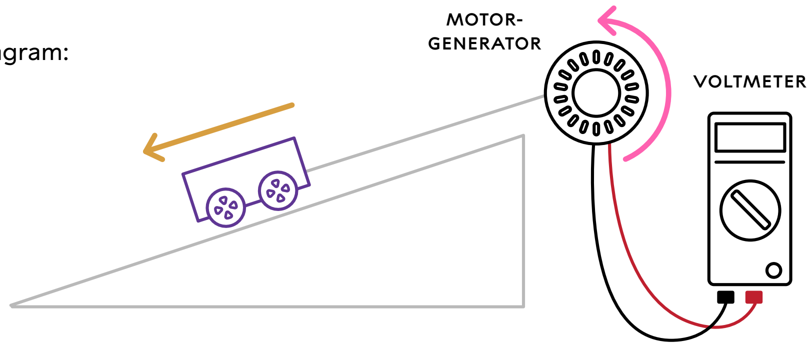
FIGURE 6.3
Gravity battery diagram: Storing energy



5 Follow your teacher's instructions to set up the discharge phase of the model gravity battery. In this phase, the cart rolls downhill to release energy.

6 With the class, work together to identify, in Figure 6.4, all the energy transformations from Step 5. Discuss how the cart rolling to the bottom of the hill is generating power. Record a sentence in your science notebook that explains what happened in Step 5 in terms of energy transformations.

FIGURE 6.4
Gravity battery diagram: Releasing energy



7 Connect the voltmeter to the motor-generator wires, using the alligator clips, to measure the voltage produced as the cart rolls downhill. Check that the hub is aligned straight over the ramp so the string will unwind smoothly during the test. It is not important if the voltage reads "+" or" –"; just record the number.

8 Charge the battery so the cart sits at the top of the hill. Then test the setup by video recording the voltmeter display as it rolls down the ramp. Review the video and find the maximum voltage released. Copy a table similar to the Gravity-Battery Data table that follows and record your data as Trial 1. It is not important if the voltage reads "+" or "–"; just record the number.

9 Repeat the charging and discharging of the gravity-battery model at least two more times (Trials 2 and 3) and then average your results.

HINT: To save energy and time, you may want to switch to winding up the cart by hand.

TABLE 6.1
Gravity-battery data

TRIAL	MAXIUMUM VOLTAGE (V)
1	
2	
3	
AVERAGE	

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PART B: MAXIMIZING THE DESIGN

10 In your group, come up with a plan to improve the model gravity battery by changing the height of the hub or the mass in the cart so it discharges a higher voltage. Make sure you plan to change only one variable at a time in the design.

11 Test your new design with the same procedure as in Part A. Use Student Sheet 6.1, "Design Testing Data: Gravity Battery," to record your data.

12 With your group, consider the results of the first design iteration. Repeat Steps 10–11 to improve the design for Design Iteration 2.

13 Continue iterating on the design until you are confident you have a design that changes one variable to maximize the voltage as the cart rolls down the hill.

14 Share your designs and test results with the class and discuss how to maximize storing energy in the gravity battery. If a gravity-battery system like this were to be built in the real world, describe the kind of location and the mass in the cart that would be best.

PART C: OTHER TYPES OF ENERGY STORAGE

15 In your group, research facts about the energy systems listed in the table. Investigate how they work, their advantages, and their disadvantages. Make sure to use credible sources in your research. Make a table in your science notebook like the one that follows and record your information in it.

TABLE 6.2
Energy storage system research

STORAGE SYSTEM	DESCRIPTION	ADVANTAGES	DISADVANTAGES	CREDIBLE SOURCE
Rail-energy gravity battery				
Pumped-hydro gravity battery				
Chemical lithium batteries				

16 In your group, take turns sharing your research with your other group members. Explain why the sources you chose for your research were credible. Discuss the advantages and disadvantages of each storage type.

17 Review the most common values from Activity 3 for the city of Vanwick. Identify the facts from this activity that relate to those values. Based on this, choose a storage system that you think is best for Vanwick's Project REV. Identify the trade-offs of the decision.

Chemical battery facility
Flevopolder, The Netherlands

BUILD UNDERSTANDING

1. 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, and
   - any trade-offs involved in your decision.

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?

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?

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?

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?

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

KEY SCIENTIFIC TERMS

energy storage system
grid sharing

SCIENCE REVIEW

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. It depends on mass, height, and the acceleration of gravity. Specifically:

> **Gravitational Potential Energy (GPE) = mgh**
>
> *where* **m** is mass of the object (in kilograms),
> **g** is acceleration of gravity (in m/s^2), and
> **h** is the height from the ground (in meters).

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

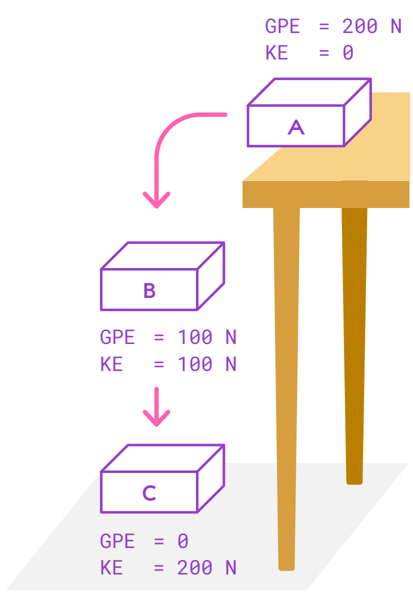
Kinetic energy is the energy an object possesses because of its motion. It is dependent on the mass and velocity of an object. Specifically:

> **Kinetic energy (KE) = 1/2 mv^2**
>
> *where* **m** is mass of the object (in kilograms), and
> **v** is the velocity of the object (in m/s).

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.

When an object is dropped from some height, it begins to lose this potential energy. It simultaneously loses gravitational potential energy while it gains kinetic energy. The total energy stays the same, as shown in Figure 6.5.

FIGURE 6.5
Example of a GPE to KE transformation



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