ACTIVITY 4

Designing Model Wind Turbines

LABORATORY

v 1.0

ACTIVITY 4

Designing Model Wind Turbines

ACTIVITY SUMMARY

Students design a model wind turbine and perform energy calculations. This lab helps them understand how many wind turbines of different sizes might be needed to meet Vanwick's energy demands. Students make connections between their experience in the lab and how scientists and engineers develop expertise. Students revisit Vanwick's values and think about how facts encountered in the activity can inform how different options might meet those values.

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 behaviors, opinions, and decisions. There can be disagreement within a community when people hold a variety of values.

CONCEPTUAL TOOLS

WEAVING FACTS & VALUES IN DECISION-MAKING

VOCABULARY DEVELOPMENT

energy transformation
the change of energy from one type to another, such as from chemical to thermal energy

power
the rate at which energy is transformed

variable
a feature, factor, or result that can change or vary

watt
(assumed prior knowledge)
the unit of power that is one joule per second

TEACHER BACKGROUND INFORMATION

Energy Transformations

The term *energy transformation* refers to the change of energy from one type (such as potential energy) to another (such as kinetic energy). Examples of common energy transformations are listed in Table 4.1: Common Energy Transformations on the next page.

Measuring Power

Power is the concept of "energy per time." The power of a device is the rate at which energy is transformed and is given as

$$P = E/t$$

where **P** is the power (in watts, W),
E is the energy (in joules, J), and
t is the time (in seconds, s).

For electrical power, this relationship is equivalent to

$$P = IV$$

where **P** is the power output of the turbine (in watts, W),
I is the current generated by the turbine (in amps, A), and
V is the voltage generated by the turbine (in volts, V).

The unit for power in the International System of Units (SI) is the joule/second, which is a watt. Watts are a measure of how much energy, in joules, is used per second. For example, household devices are categorized by the amount of power they draw, which can vary from just a few watts to a few hundred watts. A 100-watt computer consumes twice the energy than a 50-watt computer over the same time period.

TABLE 4.1
Common Energy Transformations

EXAMPLE	ENERGY TYPES BEFORE TRANSFORMATION	ENERGY TYPES AFTER TRANSFORMATION	DESCRIPTION OF TRANSFORMATION
Solar-powered calculator	light	electric, light, thermal energy	When sunlight hits the solar panels, it transforms into electricity used to run the calculator and light the screen.
Pool being heated by Sun	light	thermal energy	Electromagnetic energy from the Sun is transformed into thermal energy that warms the pool.
Candle	chemical potential energy	light, thermal energy	When burned, the chemical potential energy of the wax and wick are transformed into light and thermal energy.
Soccer player eating sports snack	chemical potential energy	thermal energy, motion (kinetic)	The chemical potential energy in food is metabolized by the soccer player and transformed into mechanical motion of playing and thermal energy that keeps the body warm.
Shocked by doorknob	motion (kinetic), electric (static)	electric, sound, light	The potential electric energy is stored up in person as an electric charge as feet rub against the floor while walking. When touching the doorknob, the energy is released from the person to the doorknob into electricity, light, and sound.
Singer	sound	electric	The singer's voice is transformed from sound to an electric signal that records the voice data.
Furnace (gas-powered heater)	chemical potential energy	thermal energy, light, sound	The chemical potential energy in the furnace's oil is burned and transformed to thermal energy and some light and sound.
Waterfall	gravitational potential energy	motion (kinetic), sound	Water falling over the dam loses gravitational potential energy and gains kinetic energy—until at the bottom it has been transformed into kinetic and some sound energy.
Photosynthesis	light, chemical potential energy	chemical potential energy, thermal energy	The plant absorbs sunlight and uses the energy to chemically combine CO2 and water into chemical potential energy for food.

TABLE 4.1
Common Energy Transformations

CONTINUED

EXAMPLE	ENERGY TYPES BEFORE TRANSFORMATION	ENERGY TYPES AFTER TRANSFORMATION	DESCRIPTION OF TRANSFORMATION
Lightbulb	electric (current)	light, thermal energy, sound	A lightbulb transforms electrical energy into light, thermal energy, and sometimes sound.
Bow and arrow	elastic potential energy	motion (kinetic), sound, thermal energy	The elastic potential energy of the bow is transferred to the arrow and transformed into motion and sound and a little thermal energy.
Combustion engine	chemical potential energy	thermal energy, sound, motion	The chemical potential energy of the gas is transformed into thermal energy coming out of the engine, the motion of the pistons, and the sound of combustion.
Fan	electric (current)	motion (kinetic), sound, thermal energy	When plugged in, the electricity is transformed into the motion of the blades, some sound, and thermal energy.
Water boiling	thermal energy	motion (kinetic), thermal energy	The thermal energy of the stove is transferred to the water, which results in steam.
Foam	elastic potential energy	motion (kinetic), thermal energy	The elastic potential energy is transformed into the motion of the foam and a little thermal energy when released.
Sun's core	nuclear energy	light, thermal energy	Inside the Sun, energy is released when hydrogen nuclei are fused and give off electromagnetic light and thermal energy.

Power and Energy

Power is often confused for energy. Informally speaking, power is the rate of energy delivery, whereas energy is the total of what was delivered over the time period in question. Electrical energy is measured in an energy unit known as the kilowatt-hour (kWh). The common term for the amount of energy drawn is *energy consumption*. This term is misleading, however, because it suggests that the energy is used up and has disappeared when it has actually been transformed and moved.

Current, Electric Potential, and Voltage

When electrons move around a circuit, an electrical current is said to flow. The amount of current (I) depends on how much charge (q) moves in a certain amount of time (t). Electrical current is measured in amperes, named for the French scientist André-Marie Ampère. One ampere is the current that is flowing at a point in a circuit when one coulomb of charge flows past that point in one second. Current is often measured with a device called an ammeter.

Electric potential is an important concept because it leads to the idea of electric potential difference. Electric potential difference is the arithmetical difference in electric potential between a final and initial location. For example, when energy is applied in order to move a charge from a potential of 10 V to a place that has a potential of 15 V, the potential difference between the lower and higher potential is 5 V. The electric potential difference is an important concept because it is what drives electrical energy through a circuit from one location to another.

Having a potential difference between two locations due to separated charges is fundamental to all electrical circuits. When a circuit, battery, capacitor, or power source provides a potential difference, it is commonly called voltage. The voltage between two terminals means that energy can do work in the circuit as the charges seek equilibrium. As long as there is a potential difference and a conducting path, charge will flow. The energy released in this way forms a current that runs devices in the circuit.

Small vs. Large Wind Turbines

In terms of power generation, large wind turbines, such as those found in utility-scale wind farms, are capable of generating more power than smaller wind turbines. This is a result of several factors—wind speeds increase at higher altitudes and larger rotor diameters and larger blades can cover a larger swept area, increasing the amount of energy collected from the wind. Generally, the size of utility-sized turbines has increased over the years, leading to increasing megawatt generation. Small wind turbines, also sometimes referred to as residential wind turbines, are not commonly used but can supplement household electricity or bringing electricity generation to places that can't be connected to the grid. Small wind systems work best in locations that are consistently very windy at low altitudes. They have many applications such as water pumping on farms or light manufacturing. New technologies, such as the Aeromine rooftop renewable energy system, are being developed to collect wind energy in urban areas but have yet to gain widespread popularity in part due to cost, lower energy generation than wind farms, and legal restrictions related to where they can be located.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 4.1 “Scoring Guide: Decision-Making (DM)” (OPTIONAL)
- ITEM-SPECIFIC SCORING GUIDE: Activity 4, Build Understanding item 1
- LARGE BOX FAN

FOR EACH GROUP OF FOUR STUDENTS

SUGGESTED MATERIALS FOR THE MODEL TURBINE INCLUDE:

- 1.5 V – 3 V MOTOR-GENERATOR
- TURBINE HUB THAT FITS ON THE SHAFT OF THE MOTOR
- 5–10 SMALL DOWELS
- SHEET OF CARDSTOCK OR THIN CARDBOARD
- RING STAND OR SIMILAR
- 2 WIRES WITH ALLIGATOR CLIPS
- VOLTMETER OR MULTIMETER
- PROTRACTOR
- RULER
- SCISSORS
- TAPE

FOR EACH STUDENT

- STUDENT SHEET 4.1 “Wind Turbine Design Testing”
- STUDENT SHEET 4.2 “Writing Frame: Decision-Making” (OPTIONAL)
- SCORING GUIDE: Decision-Making (DM) (OPTIONAL)
- SURVEY RESULTS FROM ACTIVITY 3

Determine what materials you will use in the lab and if you need to modify the procedure based on the materials you are using. Go to Appendix 3: Laboratory Setup Instructions to see how to put together a model turbine. 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 motor–generators, blades, gears, pulleys, and other essential items. 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 that are 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

For best results, use a box fan instead of a circular one. The diameter of the fan should be larger than the diameter of the turbine models that students will be building.

Familiarize yourself with operating the voltmeter or multimeter, if necessary. The voltmeter or multimeter should be set to measure DC (direct current) for a range of 0 V–3 V (ideally to a hundredth of a volt). If needed, provide instructions for students on how to use the voltmeter during the procedure.

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

TEACHING NOTES

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

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

GETTING STARTED (30 MIN)

1 **Review concepts related to energy, electricity, and energy transformations.**

- This activity is based on the principle of energy transformation—specifically, transforming kinetic energy into electrical energy. This activity assumes that students already have a basic understanding of energy transfer, transformation, and the Law of Conservation of Energy. If helpful, review the concepts of energy and energy transformation in the Science Review found in the Student Book.
- Depending on your student population, you may wish to emphasize important energy vocabulary and the relationship of these ideas to one another with a word sort. This approach presents one set of words where one word is not related to the others and another set of words that encompass the remaining words. The following three word sorts can be used to support a review of basic energy ideas. For more information on a word sort, see Appendix 1: Literacy Strategies.
- Have students copy the lists of words that follows. Instruct them to look for a relationship among the words within each list. Then, ask them to cross out the word or phrase that does not belong and to highlight the word or phrase that includes the others on the list. Note that there may be more than one correct answer to a single word sort.

LIST 1
efficiency
energy transformation
chemical energy
thermal energy
light

LIST 2
potential energy
kinetic energy
total energy
Law of Conservation of Energy
motor

Sample Student Response

LIST 1

~~efficiency~~
energy transformation
chemical energy
thermal energy
light

An energy transformation happens when wood is burned by the chemical energy in the wood, transforming into thermal energy and light that is then released into the environment.

LIST 2

potential energy
kinetic energy
total energy
Law of Conservation of Energy
~~motor~~

When potential energy is transformed into kinetic energy, the Law of Conservation of Energy says that the total energy is the same before and after the transformation.

2 **The class reviews ideas related to energy transformations, using an example of a gas generator.**

- Point out that with the exception of solar panels and batteries, electricity is transformed from generators of some type. The process requires energy transformations to take one form of energy and use it to turn a generator, which creates a different type of energy in the form of electricity. Refer to the diagram in Science Review in the Student Book to review these ideas.
- Use a Think Aloud to trace the path of energy transformations in a common diesel generator:
  1. liquid diesel fuel (chemical energy stored in bonds between atoms)
  2. burning releases heat and gases (chemical → hot gases, light)
  3. hot gases, under pressure, turn turbine blades (mechanical energy → rotational energy)
  4. generator turns (rotational energy → electrical energy)
- Contrast the use of a generator with solar panels (the latter does not spin a shaft of a generator). Solar panels have only one major energy transformation, and it is electromagnetic light to electricity. This is done when light is absorbed by semiconductors in the panel that charge electrons, causing them to flow as a current.
- Ask, What role does the generator play in releasing greenhouse gas emissions? Use this question as a formative assessment on whether students understand the significance of a generator run by fossil fuels or one spun by wind or water. Student responses should show they understand there is a big distinction between the generator shaft that is turned by hot gases from burning something, compared to shafts that are not. The former releases greenhouse gases; the latter, such as those generators turned by wind turbines and hydro (water), does not.

PROCEDURE (75 MIN)

3 Introduce the challenge of designing the model wind turbine.

- Elicit student ideas about what makes one wind turbine produce more power than another. If students do not bring it up, make sure to describe the following variables they will be testing in the lab: number of blades, blade size, blade shape, and blade angle (the angle of the blade relative to the plane of rotation). 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. This allows the experimenter to know if it is that variable and not a different one causing any changes. You might gather student predictions about how various variables might affect the performance of the wind turbine.

- Review how to assemble the basic pieces of the turbine model, using the materials you have available (see Advance Preparation). Give students any special instructions that are related to the materials they will be using.

- Demonstrate how to test the turbine by connecting it to the voltmeter and putting it in front of the fan.

  TEACHER'S NOTE: Set a standard fan speed, model orientation, and distance away from the box fan for testing purposes.

- Assign students to groups and decide which of the four variables each group should investigate: number of blades, blade size, blade shape, and blade angle. As groups get to work designing and testing the turbines, circulate and assist as needed.

4 Support students as they work in groups to design, build, and test wind turbine models.

- Provide each student with a copy of Student Sheet 4.1, "Wind Turbine Design Testing." Review the data table headings and clarify what students should write in each column. A Sample Student Response for this table is found at the end of this activity.

- Some of the following design considerations may be helpful for students as they work through iterations to their model:

DESIGN CONSIDERATIONS

Blade angle

If the blades have no pitch angle at all (they are flat and in line with the plane of rotation), the turbine will not rotate. For groups that are testing a factor other than blade angle, a default of between 10 degrees and 20 degrees is recommended. Testing blade angle is most easily done by having one student hold a protractor perpendicular to the blade, with 0 angle in line with the plane of rotation. Another student then measures the angle (pitch) of each blade against the plane of rotation as shown in Figure 4.1: Side View of Model Turbine.

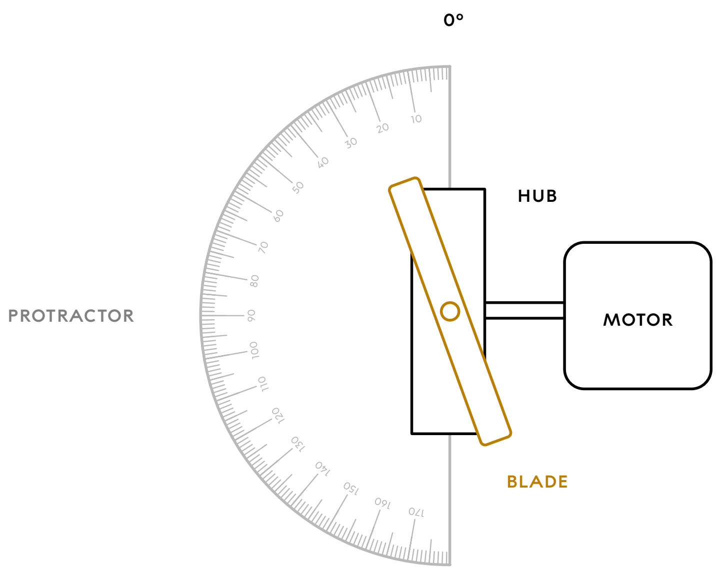

FIGURE 4.1
Side View of Model Turbine

Number of blades

Make sure the blades are evenly spaced apart. It may help to keep the area that is attached to the hub compact so more blades can easily be added.

Blade size

Students can choose to modify either the blade length, the blade width, or both. Blade size incorporates the total area of the blade. Encourage students to initially change only one of those variables at a time.

Blade shape

Students can change the whole blade shape or just the tip of the blade. They can also fold the blade or add onto the blade to change the three-dimensionality of the blade.

5 **Change student groups to develop expertise and then design the model turbine.**

- In Procedure Step 8, create new groups by instructing pairs of students to meet with a pair from another group that tested the same variable. The purpose of this is to create a group of experts for each variable who can broaden their expertise by discussing their experimental results with one another. Review the idea presented in the Introduction that an expert can include a person(s) who has firsthand experience with experimentation in a particular subject. Connect this idea with those presented earlier in the unit when students learned that it is important to gather facts from credible sources, which are dependent upon experts.

- Emphasize that for their particular variable, the new group members are more likely to know facts about that variable than others and that they can gain further expertise by discussing within their group of experts.

- In Procedure Step 9, instruct students to form into their final groups with one expert from each variable. This group will design the complete model turbine, using the combined expertise of all four variable experts.

6 **Lead a class discussion that compares similarities and differences in the designs.**

- Have students share the design aspects that impacted the output (voltage) of their models. Ask, How did each variable contribute to the output of the generator? Answers may vary based on the materials that were used and the designs that groups come up with. Generally, the different variables may affect the performance of the designs in the following ways:

IMPACT OF VARIABLE ON DESIGN

Blade angle
Designs with very small blade angles may not spin very fast as the air can't move through the design. Designs with very large blade angles may not capture enough wind to spin.

Number of blades
Designs with 2–3 blades seem to be optimal for this size and type of wind turbine. Turbines with 1 blade will not spin evenly. Having more than 3 blades makes the hub heavier, which can influence how fast the hub can spin and, thus, reduce the voltage measurement.

Blade size
The rotor hub will spin faster when the blades can capture more of the energy from the wind. Larger blades can cover a large swept area and may lead to higher voltage readings. However, larger blades also weigh more, which can limit how fast the hub can spin and may reduce the voltage measurement.

Blade shape
The shape of the blade affects the aerodynamics of the design and how effectively air can move around the blades of the turbine. Designs that incorporate a three-dimensional element into the blade design may have more effect on the aerodynamics of the blades.

- Have students share their ideas for further design changes they think might improve their results. Suggestions include making the structure stiffer, so less energy is lost when spinning; making the whole thing bigger; and/or making larger blades bigger but with a lighter material that does not add a lot of weight.

- Discuss the role of iteration of design in the activity. Ask students to compare the results of their work when they ran multiple experiments informed by their previous experiments compared to running the same number of experiments done simultaneously. This comparison should allow students to clearly see how they learned from each trial and were able to apply that knowledge as they iterated.

  TEACHER'S NOTE: If students have completed the previous unit on iteration, Evidence & Iteration in Science, they may recognize the importance of building knowledge through the process of iteration. Connect the ideas from this activity to the ones in the previous unit.

- Conclude the design portion of the activity by highlighting students' experiences establishing facts during the design iteration. Emphasize how important the role of test results (facts) was to inform their design decisions. Ask, How did the facts you gathered during testing help you produce a better design than if you had just spent extra time thinking about it? Expect students to reflect on how the process of gathering testing data helps confirm, or does not confirm, the expected outcome. Without that step, students wouldn't know if what they predicted was benefitting the design.

7 Students estimate the power generated by the wind turbine.

- In Procedure Step 14, students estimate the number of classroom model turbines it would take to power a laptop. This allows students to get a perspective on the power numbers that were calculated in Step 13, which is to say, only a small amount of power was generated by their models in relation to everyday devices. These quantities are quickly put into perspective when compared to Vanwick's current power generation of 500 MW.

  Sample Student Response, Procedure Step 14

  1.85 V x 0.1 A = .185 watts per model

  $$\frac{60\ W}{.185\ W/model} = 324\ models$$

When reviewing this estimation, discuss some of the limitations of the data used for this calculation, such as the provided estimated current and variations in the designs.

8 Students calculate power estimates in Procedure Step 15.

- Estimates for the turbines needed to power Vanwick's current electrical power needs, completed in Procedure Step 15, show that the available space for wind turbines is not enough to power the current power needs, so this is an obvious problem for the community.

Sample Student Response, Procedure Step 15

0.01 MW x 5 small turbines = 0.05 MW

8 MW x 52 large turbines = 416 MW

Total: 416.05 MW < 500 MW currently supplied

- When discussing the implications for the power estimates in Procedure Step 16, make sure students identify some of the limitations of the calculation. Important limitations to consider are 1) Vanwick's needs will be greater in the future (subsequent activities reveal that this is estimated to double in the future) and 2) the calculation shows what generation is possible, not what has yet to be decided by Vanwick. Given that the stakeholder values from Activity 3 revealed that noise and nice views are a priority, the town is not likely to choose all the locations possible.

SYNTHESIS OF IDEAS (30 MIN)

9 Introduce the assessment for Build Understanding item 1.

- Build Understanding item 1 is a decision-making assessment item. This first opportunity should be used to introduce your students to the Decision-Making (DM) Scoring Guide. As this is the first opportunity for students to review the scoring guide, you may wish to have them work in pairs or small groups to discuss and/or write their responses, using the scoring guide to help develop their responses. See Appendix 2: Assessment Resource, at the end of the Teacher's Edition for more guidance and information on using the Scoring Guide with your students.

- Do not share the item-specific version of the Scoring Guide (Item-Specific Scoring Guide: Activity 4, Build Understanding item 1) with students as it provides specific information on how to respond to the question prompt. Review the item-specific scoring guide to support scoring this specific item.

- Visual Aid 4.1, "Scoring Guide: Decision-Making (DM)," can be used to assess Build Understanding item 1. Point out the scoring levels (0–4) and review the criteria for each score. Explain that the scores are based on the quality of students' responses and reflect student growth over time. The scores do not correspond to letter grades. A Level 3 response is complete and correct. A Level 4 response signifies that the student has both achieved and exceeded the acceptable level of response. At first, many students will write Level 2 responses, and they should strive to achieve Level 3 or Level 4 responses. Let students know that you would like them to improve by at least one level as they progress through the unit. As a class, discuss what a Level 4 response to Build Understanding item 3 would include. You may develop a Level 4 exemplar as a class or share with students the

Level 4 responses from the provided sample responses. To help students better understand the three levels, discuss how they are different and ask students for ideas about how to improve from Level 2 to Level 3 and from Level 3 to Level 4.

- For some students, you may wish to support a specific level of growth—this can be particularly helpful if students have an Individualized Educational Plan (IEP), a 504 plan, or other specific educational goals. Growth from a Level 1 to a Level 2 may indicate significant progress for a student and should be recognized as such. Additionally, assessments can be a good opportunity to have students evaluate one another's work and provide initial feedback for revisions prior to submitting their responses to you.

- Sample responses for Levels 1–4 are provided in the Build Understanding section. 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 Edition for more guidance and information on using the Scoring Guides and assessment system with your students.

- An optional support is provided with Student Sheet 4.2, "Writing Frame: Decision-Making." A writing frame can support diverse learners, particularly emerging multilingual learners, in decoding scientific ideas, constructing meaning, sensemaking, and language acquisition. This strategy, which has been deemed effective for emerging multilingual learners, was built on and adapted from strategies for English-proficient learners. You may wish to provide students with the writing frame to compose their responses or simply as a reference or checklist to help them organize how they will respond. Consider posting an enlarged version of the writing frame on a classroom wall for students to refer to now and in future assessments. For more information on a Writing Frame, see Appendix 1: Literacy Strategies.

TEACHER'S NOTE: The Writing Frame is identical in all activities, despite different prompts, because it coincides with the Scoring Guide. For this activity, the two optional prompts are not used but will be in subsequent activities as student understanding of decision-making further develops.

- Conclude the activity by formatively assessing the core concepts of the activity. Evaluate if your students are able to identify the essential ideas of the activity by summarizing the key concepts and process skills.

EXTENSION (10 MIN)

10 **Use the Extension as an opportunity for advanced learning.**

Students design a solution to address the problem of birds being killed in the blades of wind turbines. Students make designs (in the medium of their choosing) to mitigate bird deaths at wind farms and then share their ideas with someone. Finally, students investigate how other engineers have addressed this problem and compare their designs with some of the solutions presented in the field.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

① **DM Scoring Guide**

Some community members think that Vanwick should use only wind turbines to power the city. If this were the case, some of the wind turbines would need to be located close to residences, near the school, and in the city park. Review the stakeholder values surveyed in Activity 3. Do you think Vanwick should decide to use all the wind turbines possible to power the city?

Explain your decision, including the following:

- **the relevant facts and stakeholder values and how they affected your decision.**
- **the predicted outcome(s) of your decision.**

Level 4 response

I do not think Vanwick should use all wind turbines to power their city. I have decided this based on several facts and values. The facts I used to inform my decision are that Vanwick needs 63 large turbines to meet their power needs. Although Vanwick does have the space to install this many turbines, the turbines would need to be located close to residents' homes, near the school, and in the city park. I also considered the stakeholder values from the survey of Vanwick residents, and one of the top values for many residents is to not have the renewable energy sources close enough to see or hear. Therefore, I think that Vanwick should use as many wind turbines as they can, without building them close to homes, schools, or the park. The outcome of this would be a partial solution to their energy needs, but they would need additional renewable sources of energy to provide the rest of the power needed by their residents.

Level 3 response

I do not think Vanwick should use all wind turbines to power their city. I have decided this based on the fact that they would have to build turbines near people's homes. One of the top values from the survey was to not have renewable energy sources close enough to see or hear. If they do not build enough wind turbines to provide all the power they need, the outcome will be that they won't have enough power, or they will need to find other renewable sources.

Level 2 response

I do not think Vanwick should use all wind turbines. They need 63 large turbines, and that is a lot. People don't like the noise from the wind turbines, so they should not use all wind turbines.

Level 1 response

I do not think Vanwick should use all wind turbines. People like solar panels more because they are better.

② **Facts about the maximum amount of power generated by different-sized wind turbines were presented in this activity. However, the actual power generated at any given moment is usually lower than the maximum generation rate. For example, the average power generated by a wind turbine is 20%–40% below the maximum.**

a **Make a list of variables that can affect the amount of power produced by wind turbines.**

Variables for wind include amount and direction of wind, weather condition, time of year, design of turbine.

b **How would these variables affect the number of turbines needed to meet Vanwick's power needs?**

You would need to install more wind turbines to meet your power needs because if the factors listed above cause there to be less power generated than expected, then you will not be able to meet the power needs unless you have more units installed or a different kind of generation as backup.

CONNECTIONS TO EVERYDAY LIFE

③ **Imagine you know someone who has an electric car. It is charged by plugging it into an electrical grid. The grid is powered by a coal power plant. They make the following claim of fact:**

This vehicle provides zero emissions to the atmosphere.

a **Do you agree or disagree with their claim of fact? Explain.**

I disagree with their claim. The fact that the grid is powered by a coal power plant means that there are emissions associated with the generation of the electricity that powers the car. Also, there might be emissions related to the manufacturing of the vehicle.

b **Suppose the person provided an information source to their claim of fact. Would that change your thinking about the claim of fact? Explain why or why not.**

It depends on the type of information source they give. If it is not from a credible source, then I would need my friend to find one to make me rethink my position.

REFERENCES

Sivak, A. (2019, May 22). AI-backed sensors help reduce wind turbine risks to protected birds. *Earth Island Journal*. Retrieved from https://www.earthisland.org/journal/index.php/articles/entry/sensors-reduce-wind-turbine-risks-to-birds/

STUDENT SHEET 4.1

WIND TURBINE DESIGN TESTING

NAME

VERSION	VARIABLE BEING TESTED	DESIGN DESCRIPTION OR DRAWING	DESIGN REASONING	MAX VOLTAGE (V)	OBSERVATIONS
1					
2					
3					
4					
5					

STUDENT SHEET 4.1

WIND TURBINE DESIGN TESTING

NAME SAMPLE STUDENT RESPONSE

VERSION	VARIABLE BEING TESTED	DESIGN DESCRIPTION OR DRAWING	DESIGN REASONING	MAX VOLTAGE (V)	OBSERVATIONS
1	*blade angle*	*2 blades, opposite each other, trapezoid shape* *blade angle of 45°*	*Having the blade at 45° will work better than 0° because the wind will catch and move it.*	*0.45 V*	*Having the blades exactly opposite each other works better.*
2	*blade angle*	*2 blades, opposite each other, trapezoid shape* *Blade angle of 20°*	*The blade will not work as well at 20° to catch the air.*	*1.35 V*	*The smaller angle causes the blades to move faster!*
3	*blade angle*	*2 blades, opposite each other, trapezoid shape* *Blade angle of 0°*	*The blade may work even better by catching all the wind.*	*0 V*	*The blades do not move at all now. They need to be at least at a slight angle.*
4	*number of blades*	*Blade angle of 20° and all are a trapezoid shape* *4 blades spaced evenly apart*	*More blades might go faster by catching more wind.*	*1.10 V*	*It wasn't quite as fast. Maybe because the blades make it heavier to turn?*
5	*number of blades*	*Blade angle of 20° and all are a trapezoid shape* *3 blades spaced evenly apart*	*Maybe it will go faster because of less weight.*	*1.18 V*	*It still wasn't quite as fast as just 2 blades.*

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 4.2 | 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

VISUAL AID 4.1 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 explains their decision about whether Vanwick should use all wind turbines, incorporating the following:** • 2–3 relevant facts (number of turbines needed to meet energy needs, how much space is available, where turbines would be built if all turbines needed are built) • stakeholder value of not wanting to see/hear renewable energy sources • meeting stakeholder value leads to the all-wind-turbine option not being possible • outcome is not enough renewable power or additional renewable sources needed **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 explains their decision about whether Vanwick should use all wind turbines, incorporating most of the following, BUT one or more may be insufficiently described:** • 2–3 relevant facts (number of turbines needed to meet energy needs, how much space is available, where turbines would be built if all turbines needed are built) • stakeholder value of not wanting to see/ hear renewable energy sources • meeting stakeholder value leads to the all-wind-turbine option not being possible • outcome is not enough renewable power, or additional renewable sources needed **However, additional relevant facts, values, and outcomes may be considered.**
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 explains their decision about whether Vanwick should use all wind turbines, BUT the explanation of supporting facts and values is incomplete (e.g., only one fact, not including values, not stating possible outcomes).

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
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 states their decision about whether Vanwick should use all wind turbines BUT provides inaccurate or unrelated facts, unrelated values, and/or an illogical explanation of the decision.
Level 0 **Missing or off task**	The student's response is missing, illegible, or irrelevant.	
X	The student had no opportunity to respond.	