Investigation Guide: Using Real-Time Electricity Data to Spark Student-Led Investigations

Overview

Students examine different types of electricity data available to homeowners. They engage in a series of investigations, designed to help a "mystery" homeowner use the available data to understand and reduce electricity use and costs.

Teacher Background

Engaging students in complex, challenging real-world problems is key to preparing future generations with the essential skills and knowledge they'll need to be informed members of an increasingly technological society - one which is becoming abundantly populated with data from sophisticated "smart" technologies. This investigation guide is designed to help teachers facilitate student-centered investigations using real-time electricity data from emerging monitoring devices (e.g. smart meters and home electricity monitors such as The Energy Detective or TEDs and eMonitor). In addition to allowing for real-time measurement of household electricity, use of such tools has been found to be a powerful motivator for learning and aid in making electrical energy more readily perceived as quantifiable and "tangible" – something the research on student learning reveals as difficult for middle school students. Using real-time data also has the capacity to allow students to be comfortable analyzing numerical data and using the data in meaningful ways. If the expectation is to have a citizenry able to make decisions about, act responsibly in, and take steps toward conserving its energy use, it is critical that students' educational experiences begin early. In this investigation, students work as scientists, collecting and analyzing real science data for a contemporary and very relevant problem. As teachers engage students in collaborative activities and investigations using these new data collection tools, it is expected that they learn and solve problems alongside their students – working together to understand electricity, how it's used and how new technologies in electricity monitoring help in making evidence-based decisions in the development of strategies for conservation.

At the time of this writing, Maine's largest electric supply companies (Bangor Hydroelectric and Central Maine Power Company) have joined utility companies across the country installing "smart" electricity meters. Bangor Hydroelectric reports that it has approximately 116,000 smart meters already deployed to residential customers within their service territory, which is 97% of their total meters. These installations were completed in 2005. The remaining 3% of meters are scheduled to be installed by the end of 2011. Central Maine Power began its smart meter installation in September, 2010 and expects to finish in early 2012. When installation is complete, Maine will have the highest concentration of smart meters in the nation, projected to be at 95% of customers. Both utility companies have additional information regarding smart or automated meters on their respective websites: http://www.bhe.com and http://www.cmpco.com.

Until all customers can access the real-time data smart meters provide, this investigation guide is built around using an intermediate electricity monitoring device, namely "The Energy Detective" or TED in conjunction with Google PowerMeter (www.google.com-powermeter) to access and share electricity data from the home for student investigations. To learn more about how this particular electricity technology works visit www.theenergydetective.com. Consult the references and resources section of this guide for additional information on home energy monitoring devices. Once smart meter deployment and the customer interface have been completed the guide will be updated. Teachers in Maine interested in carrying out the investigations outlined in this document that do not currently have access to real-time electricity use data may request access to the mystery homeowner, Addison Fox's, data by contacting info@powersleuth.org.

Unlike traditional dial meters, smart meters have digital displays, are wireless, and use a radio frequency band for two-way communication. The installation of these new meters is just one component of a system-wide upgrade to a "smarter" more automated power grid system, a system which has been virtually unchanged since its development in the early 20th century despite the rapid increase of high-tech digital devices coming online. Smart meters monitor and record the amount of electricity (or gas in some areas outside of Maine) a homeowner uses and sends this information to the electricity provider. This constant communication between electricity provider and consumers enables the utilities to have up to the minute information about system wide demand and to make adjustments accordingly. This constant communication also instantly alerts the utility to power failures instead of relying on its customers to call in outages.

Electricity is generated constantly – every second of the day, every day all year long since at the present time, electricity cannot be stored on a large-scale basis. In the traditional system, keeping the perfect balance of how much electricity needs to be generated and pushed out over transmission lines to meet demand has been left up to people in control rooms who constantly monitor and adjust how much electricity is being generated with how much electricity is being used. Although the current system has been fairly reliable, people across the United States experience blackouts, brownouts and other power outages resulting in high costs and major inconveniences. Being able to adequately balance power needs to regions during times of high and low demand is one of the most complex aspects of electricity management. This balancing act becomes automated and fine-tuned in a smart power grid system as increased communication allows for faster responses to changes in demand. Keep in mind the U.S. power grid includes a mix of types of power plants generating electricity. Hundreds of thousands of transmission lines crisscross the nation connecting power plants and substations. Coordinating and synchronizing these efforts is no easy task! Including "greener" methods of generating electrical energy, such as wind and solar power, also requires a "smarter" grid system.

For the consumer, this ability to access real-time use translates into increased awareness and more informed choices about when and how electricity is used in the home. Maine's utility companies are in the process of developing the way homeowners will view the smart meter data, but typically information is accessed via the web and/or by using table top monitoring stations, making it fairly straightforward to see what happens when one turns on an appliance that draws a lot of electricity such as an electric clothes dryer! Homeowners can monitor their electricity use patterns and make adjustments to how much and when they use power to avoid using electricity during times of heavy demand on the electrical system (known as "peak" hours). Reducing electricity use during times of peak demand is a powerful way to reduce electricity and environmental costs. During times of peak demand, less efficient power plants are brought online. These plants are both more costly to operate and have greater environmental impacts. Many utility companies in other parts of the country charge their customers higher rates for electricity use during peak hours and lower rates for use during off peak hours (known as "time of use rates" and often abbreviated TOU). At this time, Maine residents are not charged higher rates for using electricity during peak times. However, both Bangor Hydroelectric and Central Maine Power do offer optional time of use rate plans to their residential customers but few customers are enrolled in these plans.

Despite the apparent benefits of smart metering technologies, people in Maine and elsewhere have raised concerns about the installation of smart meters. While concerns vary, some worry that the radio waves emitted by smart meters are harmful to people's health.

Others who live in homes with older wiring are concerned that adding a smart meter to their home will put them at risk of fire. People in other states where smart meters have been installed have questioned the accuracy of the new meters because they have reported that their electric bills in some cases have increased after smart meters were installed. Some have raised concerns regarding their privacy due to the way information about use is transmitted digitally in smart grid systems. The Maine Public Utilities Commission is investigating all of the concerns and its findings are made public on their website **www.maine.gov/puc**. Central Maine Power has compiled answers to the questions and concerns people raised regarding smart meters on their website: **http://www.cmpco.com/**

For students, having the opportunity to engage in long-term ongoing investigations around situations that matter to them sparks their curiosity, provides them with motivation to learn, and puts them ahead of the curve in developing an understanding of how these new tools work and can be used to significantly impact how consumers use electricity. As noted previously, this lesson plan requires access to real-time electricity data which the majority of homeowners in Maine and across the nation will have access to shortly (consult electricity providers in your area for specific dates). The scenario used to set the stage for the investigation is this - students are invited to help a homeowner – a "mystery" person - examine the different types of electricity data available. This includes data from new tools that allow the homeowner to monitor how much electricity s/he is using while s/he's using it. Students engage in a series of investigations and activities using these new tools and other resources to answer questions about the mystery person's home electricity use. As students study how electricity is used in the home, they also learn how electricity is measured, how customers are charged for its use, patterns of use and how much electricity common household appliances use. Students use these findings to make recommendations to the homeowner and to a broader audience for conserving electricity. As accessibility to real-time electricity data becomes more widespread, additional investigations – ideally those involving students' own electricity data – will become an option.

These materials are aimed at helping teachers facilitate student-centered scientific investigations and were designed to allow for flexibility. A number of options and activities are offered so that the teacher may customize the instructional sequence to best meet students' needs and interests. Teachers have found it helpful in planning to use the *Investigation Guide: Using Real-Time Electricity Data to Spark Student-Led Investigations* as the backbone or main framework for instruction. Included is an Investigation Guide and Supplementary Activity Matrix which gives an overview of each of the components and offers suggestions about how the activities might be connected. As teachers plan they should keep in mind students' prior experiences in carrying out investigations and recognize that certain aspects of scientific investigations present considerable difficulties for 7th and 8th grade students, most notably developing investigable questions, writing claims supported by evidence, summarizing and analyzing data. Most will need support in detecting trends in data and while middle school students can often compute statistical measures such as mean, median, mode, percent change and the like, their understanding of what these measures indicate and how best to use them is underdeveloped. The units of electricity (Watts, kilowatts and kilowatt hours) are quite unlike others students may have encountered in the past. The investigation sequence presents numerous opportunities to bring in mathematics (e.g. examining the area under the curve, exploring the meaning of slope, describing changes over time), and teachers are encouraged to capitalize on these connections, as learning situated in real world contexts is extremely effective and synergistic.

Key Ideas

- Electric bills, meter readings, and real-time electricity monitoring devices document actual electricity use in the home.
- Electrical energy can be quantified and compared.
- There are many questions that can be investigated using electricity data. Asking appropriate questions is key to driving scientific investigations.
- Ongoing investigations provide evidence for solving problems, including developing strategies for conserving electricity.

Investigation Goals

Students will :

- develop an understanding of and examine electricity use data.
- describe and interpret patterns of household electricity use.
- design and conduct an investigation to answer a question about electricity use in the home.
- apply investigation findings and make recommendations for reducing the amount of electricity used in the home.

Vocabulary

investigable question: questions that can be investigated or answered by doing something concrete with tools, materials, and/or data sets. Sometimes also called testable questions.

kilowatt (kW): 1000 watts

kilowatt hour (kWh): the number of kilowatts used in an hour. The kilowatt hour is the most commonly used unit for measurement of electricity consumption.

researchable question: questions that can be answered through print research and/or by consulting with an expert in the field. Researchable questions tend to be more factual in nature and (often) do not lend themselves well to being answered by investigating with available tools and materials.

Watt (W): a unit of power used to measure electricity.

Preparation

- Become familiar with this guide as there are several approaches outlined in supporting students as they work through the investigation.
- Consult the Investigation Guide and Supplementary Activity Matrix which outlines the key ideas and learning goals for each activity. While the matrix does not prescribe an activity sequence, it can be used to help teachers consider which activities to include and how to best sequence them. The matrix and narrative portions of this investigation guide also identify opportunities and strategies for assessing students' understanding.
- Become familiar with the data students will access in this investigation.
- Determine what data will be used for the "mystery" homeowner data and how students will access the data. This includes deciding which electricity bill(s) will be used in Step 1. Requests for accessing Addison Fox's data, may be sent to info@powersleuth.org.
- Be sure to consider and protect the privacy of the homeowner.
- Determine the platform students will use to share findings (electronic and/or face-to-face).

Materials

Item	Quantity
Scientist's Notebook	1 per student
Computer(s) and/or LCD projector (for class use)	1 per class minimally; one computer per student preferable
Chart paper and markers	1 per class
Index cards (20-30) or chart paper cut into strips (several)	1 set per pair/group
"Please answer my questions about electricity use" email	1 per class
"Is this helpful? Meter readings?" email (optional)	1 per class
"Check this out – Google PowerMeter" email	1 per class
Sample Electricity Bills (e.g. BH, CMP, MPS)	1 per student or pair
How to Read Your Electric Meter	1 per student or pair
Investigation Planning Guide	1 per student or pair
Additional activity handouts as determined by teacher (See Instructional Guide and Supplementary Activity Matrix)	variable

Time Required: 5-10 sessions*

*It is strongly recommended that the investigative sequence be repeated an additional time to provide students a second opportunity to practice and further develop their skills and refine their investigation. Consider spreading out the investigation outlined over a span of one or two months to enable students to work with data that has been collected over a longer time period.

Connection to *Maine Learning Results (MLR), Benchmarks to Science Literacy (BSL), National Science Education Standards (NSES),* and *Common Core State Standards for Mathematics (CCSS):*

- Scientific investigations usually involve the collection of relevant data, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected data. BSL 1B/M1b*
- Organize information in simple tables and graphs and identify relationships they reveal. BSL 12D/M1
- Understand oral, written, or visual presentations that incorporate circle charts, bar and line graphs, two-way data tables, diagrams, and symbols. BSL 12D/M4*
- Present a brief scientific explanation orally or in writing that includes a claim and the evidence and reasoning that supports the claim. BSL 12D/M6**
- Use appropriate tools and techniques to gather, analyze, and interpret data. NSES A (5-8)
- Describe rates of change and cyclical patterns using appropriate grade-level mathematics. MLR A3 (6-8) c
- Students plan, conduct, analyze data from, and communicate results of investigations, including simple experiments. MLR B1 (6-8) a-f
- Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number. CCSS 6.SP.3
- Summarize numerical data sets in relation to their context, such as by…relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered. CCSS 6.SP.5
- Recognize and represent proportional relationships between quantities. CCSS 7.RP.2
- Use proportional relationships to solve multistep ratio and percent problems. Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error. CCSS 7.RP.3

✔ *Modified versions of Energy for Maine, Lesson 1: Electricity Discovery Box or Lesson 6: Maine's Electricity Picture can be used to preassess students' understanding of electricity and/or build background information prior to the start of the investigation.*

Facilitating the Investigation

Engage

[Session 1]

1 **Set up the mystery person scenario.** Share with students the email from Addison with the subject line "Please answer my questions about electricity use." Provide students with a copy of Addison's electricity bill. Ask students to work with a partner to examine the electricity bill. Pose the following question: *What information can you find on an electricity bill?* Direct students to identify and list in their notebooks specific information found on the bill. Encourage students to think broadly about the information that can be gleaned from the bill.

> **Note:** *Alternatively provide students with a sample bill from the electricity provider in their area. Additional sample bills from Maine Public Service, Bangor Hydroelectric, and Central Maine Power are included in these materials. As an extension, consider providing students with different bills and comparing the information available on each.*

Once students have finished making their lists, call students together and create a class chart of the specific information that they have identified. Information that students may find include: the electricity company's contact information, service location, billing date, current balance, prior balance, new charges, electricity deliverer and supplier information, total charges, amount of days in the billing cycle, the account number, message about receipt of payment, account balance, amount of money spent on delivery, daily use, monthly use, address for sending payment, due date of bill, place to write amount paid, actual number of kilowatt hours used, etc. Consider displaying a copy of the bill on an overhead or LCD/computer and as students share the information they found, verify where this information is located on the bill and clarify through questioning what this information means. Keep track of questions students have about the bill as they arise on a separate piece of chart paper.

Explore

2 Determine information and data relevant to Addison's electricity use questions.

Once information found on the bill has been shared, revisit Addison's email to clarify the questions being asked. Write these focus questions on the board and/or ask students to record them in their notebooks:

- *Why does the amount of an/my electricity bill change each month?*
- *How does the power company figure out my monthly cost?*
- *In what way does the amount of electricity I use change each month?*
- *What suggestions do you have for helping me predict how much electricity I might use over the course of a year?*

Upper middle school students likely have given little thought to and/or have limited knowledge about how people are charged for electricity and will likely have questions very similar to Addison's! Before students work toward answering Addison's questions, engage in a brief discussion to clarify the questions being asked and make clear the differences in the questions being asked. Help students recognize that some of the questions Addison asks are more informational in nature and other questions involve using data. For example, *"Why does the amount of an electricity bill change each month?"* involves understanding that consumers are charged by the number of kilowatt hours (kWh) they use during a given billing cycle and is informational in nature. The number of kWh changes from month to month due to a variety of factors (i.e. number of days in billing cycle, season, types of appliances they have in their homes, etc.). Students will have the opportunity to investigate these factors in more depth but these points may surface in these early conversations. The remaining questions *"How does the amount of electricity I use each month change?"* and *"What suggestions do you have for helping me predict how much electricity I might use over the course of a year?"* are ones that involve working with data available in monthly electric bills.

An additional conversation to have with students before they develop a response to Addison involves reexamining the class list they generated of the information found on the sample bill. Refer students to the list and identify (perhaps by placing a check mark or other notation next to each item) which items might be helpful in answering Addison's questions. The point to make is that the bill contains a lot of information, and it is important to determine which pieces are relevant in helping answer the questions.

Note: *Consider carefully how much detail is presented to students about how customers are charged for electricity at this time. They should recognize that charges are based on the number of kWh used each month. A detailed explanation of how the bill is calculated is included in the next teacher note, but providing all of these details at this time may be unnecessary. Teachers may opt to have students discover mathematically the pricing structure through calculations and graphing which could be introduced now or as a supplement to future lessons. Examples of activities that will further investigate the pricing structure are described in matrix of supplementary activities. Students may also begin to wonder how Addison's electricity use compares to average use in Maine households or their own – an opportunity for additional research.*

Encourage students to convey answers to Addison's first two questions ("Why does the amount of my electricity bill change each month?" and "How does the power company figure out my monthly costs?") broadly in a way that connects charges to use and attributes differences from month to month to different amounts of electricity being used. For the last two questions, there is opportunity for students to include graphical representations of data and to engage in statistical analysis of monthly kWh (mean, median, mode, percent change or some other method). Give students a few moments to brainstorm in small groups or pairs what types of representations and analysis might be beneficial in answering the questions posed. Discuss students' initial ideas as a class.

Note: *In this particular example, the total number of kWh used from 11/29/10 to 12/28/10 (approximately 1 month) was 620 kWh. The utility company charges $8.41 for the first 100 kWh used each month and for every kWh after that charges $0.059819 per kilowatt hour. This means for 620 kWh, $8.41 is charged for the first 100 kWh and $31.11 is charged for the remaining 520 kWh (520 x $0.059819) bringing the total to $39.52. This amount differs from the total amount shown on the bill because the utility charges additionally for such things as providing the network for the electricity to get to your home. In Maine, electricity companies own the wires, poles, transformers, meters, and other equipment needed to deliver the electricity to our homes and businesses. The price for their service appears on electricity bills as "delivery service" and these fees get added to the amount of kWh used during the billing cycle.*

✔ *The activity Next Month's Electricity Use can be used here as a supplement or an assessment.*

[Session 2]

3 Prepare responses to Addison's questions.

Support students as they work on developing a response to Addison's questions regarding electricity use. There are several ways students can be organized to work through the focus questions depending on the time available and class characteristics.

Option A: Small groups of (3-4) students can work through all four focus questions. Consider having students work on the first two focus questions initially and then the second two focus questions as these lend themselves to digging deeper into the available data. Encourage students to create graphic representations of data as appropriate to support their responses.

Option B: Assign small groups of (3-4) students to work on one of the four questions. Step 4 below can be used as a 5th question and assigned to a small group if the work is to be divided among the class.

Regardless of the approach, allow time for students to discuss, critique, question, and make suggestions to each group's responses. Allow additional time for students to make improvements and modifications to their responses.

4 (Optional) Share the second message from Addison about meter readings.

One of the pieces of information that students may find listed on their sample electricity bill is the meter reading. Share the second message with the subject line "Is this helpful? Meter readings?" with the class. Clarify what an electricity meter is, discuss where they are likely found, the different types (dial and smart), and how they are used by the electricity company to determine how much electricity is used in a particular home, business, or school. Students may be interested in learning how dial type electricity meters are read. Use the handout developed by Maine Public Service http://www.mainepublicservice.com/education/electricity-education.aspx, to teach students how to read a dial meter. Encourage students to find the electric meter at their home and keep track of their daily electricity use over the course of several days. Ask students to write a response to Addison's email sharing what they've learned about electric meters.

[Sessions 3-4]

5 Introduce real-time data monitoring.

Option A: Share the message with the subject line "Check this out – Google PowerMeter" with students. Provide students with access to Addison's real-time electricity data. Remind students of the new questions posed:

- *What information does the graph show?*
- *What does this representation show that an electric bill doesn't?*
- *How do you think this additional data can be used to help reduce electricity use and costs?*

As students examine the real-time electricity graph for the first time they will need to spend some time initially getting a sense of how to read the graph and support in figuring out what information is shown.

> **Note:** *There is a lot of information available to students via the TED - Google PowerMeter interface or whatever real-time monitoring device being used. The more students work with the information, the more they will discover and want to investigate. Keep in mind and bring to students' attention when appropriate: The Google PowerMeter scale showing how many kW varies, and the fact that it changes may be overlooked by students until they work with data over time. The bar showing "expected usage" appears only after a TED has been collecting data for a week. The "always on" amount changes over time. TED sends data to the Google PowerMeter interface every 10 minutes.*

Once students have developed some familiarity with the real time data, ask them to briefly discuss in pairs what a response to Addison's first two questions might include. Give students a few minutes to individually write a draft response to Addison in their scientists' notebooks. Bring the class together in a scientists' meeting to discuss the key elements to include in the response to Addison. Draft a class response that includes these key elements.

Option B: Share the message from Addison as described in Option A. Provide students with the Going Graphic handout. Alternatively, provide the raw data of electricity use from another day/source. Helpful hints and tips for pulling together a different data set using a TED is in the Going Graphic Teacher Notes.

Engage in a conversation about data and include the following points:

- *What is this data? In other words, what is being observed or measured?* Real-time electricity use is being measured.
- *How was it collected/recorded? How was it generated?* Every 10 minutes, TED measures and records the number of kilowatts of electricity being used at the home. The data table shows the readings for May 16, 2011.
- *What is the purpose of a data table? Why is data often presented/displayed in tables?* The purpose of a data table is to provide information. Scientists in different fields collect data in many differ-

ent forms. Often one quantity in a table depends on or is related to another. Commonly when data is initially compiled it is displayed in a table; it almost always is later displayed in a graphic form for a number of reasons. Data displayed graphically makes visualizing and interpreting the data easier and aids in analyzing variation.

Ask students working in pairs to determine a way to make a graph of the raw data. Before constructing a graph, discuss with students:

- *What are graphs used for? Why do we use graphs?*

Student responses will likely contain the following points:
- to communicate information to other people
- to identify trends in different variables (interpretation)
- to identify how one factor affects another (correlation)
- to help understand what the data represents (analysis)

Have students work in pairs to create a graph of the data from the data table. Before they construct the graph, instruct students to do some initial brainstorming of what they want the graph to show - what is the graph's purpose? Said differently, students should consider what question the resulting graph answers. What type of graph is appropriate? Line? Bar? Something else?

> **Note:** *One of the purposes of doing this graphing exercise is to help students develop a sense of what the real-time electricity use display shows. The data can be thought of as representing snapshots of use at particular times (10 minute intervals) during the day. These snapshots do not represent cumulative electricity use (kWh) but could be used to estimate (calculate) cumulative energy use. Advanced students might be interested in examining how the data is related to cumulative use. This data set could be modified to show data in less frequent intervals – perhaps 30 minute intervals – which would make the data set more manageable. Keep in mind however that TED home energy monitors viewed using Google PowerMeter show 10 minute intervals and students may not see a clear match between the way they've graphed the data and the way Google PowerMeter graphs the data if the time intervals differ. Another way to make the graphing task more manageable is to have students graph a portion of the graph – perhaps one of the six tables shown on the student handout.*

Once students have completed their graphs, debrief by having students share the graphs they constructed with each other. Students can discuss similarities and differences and discuss the strengths and weaknesses of the displays. Share with students the handout showing the Google PowerMeter display for May 16, 2011, and ask students to compare and contrast this to their own graphs. What story do each of the graphs tell? As an extension, the discussion can segue into a conversation about why they think Google made the decision to display the TED data the way they did – what question does it answer? What story does the graph tell? There is also opportunity for students to see the same data graphed using different time intervals by sharing the resource page handout Two Views, Same Data.

[Session 5]

6 **Generate investigable questions.** Revisit Addison's latest message. Ask students what ideas they have about the comment: *"I would really like to dig into an investigation of my home electricity use. Can you suggest a question we could investigate together?"*

> **Note:** *There are different ways to facilitate the generation of investigation questions. The approach described below is one that provides students with the opportunity to generate the question. The teacher may opt to provide the (initial) investigation question. Regardless of how the investigative question is generated, keep in mind that the question directs the collection and analysis of data.*

Provide pairs of students with long strips of chart paper or 20-30 index cards. Instruct students to work with a partner and carefully examine the real-time data. Encourage students to brainstorm questions about what they are noticing and wondering about this homeowner's electricity use. Explain that students are to write any questions that come to mind- without censoring or editing ideas – on an index card or strip of paper - one question per card/strip. However, remind students that Addison is particularly interested in reducing electricity use and costs.

Ask students to sort their questions into two piles: investigable questions and researchable questions. Provide students with the following descriptions and perhaps sort through some examples together:

- Investigable questions are questions that can be investigated/answered by doing something concrete with tools and materials such as examining real-time data displays, electricity bills, Kill A Watt meters, etc. These types of questions are sometimes also called testable questions.
- Researchable questions are questions that are best answered through print research and/or by consulting an expert in the field. They tend to be more factual in nature and do not lend themselves well to being answered by investigating with tools and materials.

> **Note:** *Investigable questions developed using a "mystery" person's data have additional parameters that students should be aware of. Investigable questions will be those that can be answered by using the available data as students will not have direct access to the homeowner. In other words, investigation questions are limited to those that can be answered by the data they can access via the real-*

time electricity display in this case, Google PowerMeter. Examples of questions that students have investigated can be found on the PowerSleuth website.

Circulate among students as they work, listen to their conversations, and help clarify any questions they have.

Once students have finished sorting their questions, ask them to post their questions on the wall under the two headings: investigable and researchable. Facilitate a brief review of the questions they've generated. Group similar questions within the two categories together and discuss similarities and differences within and between the two groups. Ask students to consider what makes a question investigable? Students should recognize that investigable questions involve taking action, often using equipment or tools to collect first-hand information and is one that can be carried out given the time and materials available. Answering investigable questions involves collecting data, analyzing the data, and providing supporting evidence. Investigable questions often begin with "What will happen if…," or include things like "How does ___ affect ___? Which …? The phrasing of questions leads to taking action. Questions that begin with "Why" are requesting information rather than suggesting an action and generally these questions can be answered using print or online reference materials or by asking an experienced, knowledgeable person. Make the point to students that both kinds of questions are valuable; in other words, investigable questions are not "better than" researchable questions. Also worth noting is the idea that sometimes researchable questions can be turned into investigable questions by making slight modifications.

Once students identify those questions that they think are investigable, do a "question check" with a sampling of questions students are interested in investigating. Ask students to consider the following:

- *Does the question relate to the problem identified in the opening scenario?* Is this related to what the mystery person (Addison Fox) wanted to find out?
- *Can the question be answered with a response of just "yes" or "no"?* Yes or no questions don't lend themselves to rich investigations.
- *Can the question be answered by gathering evidence? (From the graph only?)* Do we have access to data that would answer this question?
- *Is the question so broad that it will require multiple investigations?* Consider narrowing (e.g. specify time period month, particular day, particular hours)
- *Does the question identify a relationship or factor that can be investigated?*

Note: *Consider asking students to investigate questions that would bring in other data. For example, students may wish to investigate whether the role of such things as temperature, sunrise/sunset, weather conditions, etc. factor in to home electricity use. Investigations that rely on two data sets may be preferred for second round or follow up investigations.*

[Sessions 6-7]

7 Identify investigation question and develop investigation plan. There are several ways to approach this initial investigation. Select an approach that will provide a successful and engaging experience for the class and one that fits within the time available.

Option A (Class selects one investigable question): Have the class choose one investigable question by revisiting the list of investigable questions generated. Ask students to place a check next to a question they find most interesting or write their top three question choices on a piece of paper and tally the results. It also may be helpful to discuss the types of investigations that each of the top 3 questions might lead to before committing to a question.

Option B (Each small group selects one investigable question): Follow a similar process to the one outlined above except allow each small group of students select an investigable question from the list generated by the class. Allow groups time to think through and discuss the actions each question in contention might lead to.

Option C (Teacher selects one investigable question): The teacher selects a question from those generated by students or provides students with a question developed ahead of time.

Distribute a copy of the Investigation Planning Guide to each student. Allow students time to plan how they will carry out their investigation using the guide. Direct students to record their investigation plan in their scientists' notebooks. Assist students as needed. Note any common questions or difficulties that arise as students are planning and address these appropriately in the discussion that follows.

Review students' plans (this can be done either by the teacher or by peer review). Allow time for students to make modifications and improvements as needed.

Note: *This is an opportune time to use one or more of the activities described in the Investigation Guide and Supplementary Activity Matrix if investigations are designed such that students will need to collect data over an extended time period. Activities that can be used here include Appliance Card Sort, How Many Ways to a Kilowatt Hour Scavenger Hunt, Graph Match, Developing a Narrative from a Graph, and Developing a Graph from a Narrative. Making a Statement can be used to help prepare students make accurate claims based on evidence.*

8 **Carry out investigations and share findings.** Allow students time to work in small groups to carry out their investigation. Assist student groups as they collect and analyze data, organize data, write a conclusion and prepare to communicate their findings to others either face to face or using an electronic forum. Students will share their findings via an electronic forum (i.e. Moodle, Study Wiz, Google Docs) and be asked to discuss and make comments about their peers' work in this forum. Alternatively have each group present their findings to the class. Student presentations should be concise and reflect the following:

- Statement of investigative question
- Statement of their prediction
- Statement of their results (conclusion based on evidence). This includes referencing a graph.
- Recommendations to Addison

Reflect and Discuss

[Session 8]

9 **Summarize learnings and generate new questions.** Bring the first investigation cycle to a close by summarizing learnings and reflecting on the work students accomplished. Additional questions will undoubtedly be generated as students work through their investigations. Collect these questions and have students examine and select another investigative question to answer following the steps outlined earlier.

Note: *Several of the activities described in the Investigation Guide and Supplementary Activity Matrix are aimed at helping students deepen their understanding of specific aspects of the investigation and can be used following the completion of the first round of investigations. For example, Graph Match, Developing a Narrative* *from a Graph, and Developing a Graph from a Narrative provide additional experiences with recognizing how different electricity use scenarios might look on a real-time graph. Appliance Card Sort, Energy for Maine Lesson 7: Watt's in a Nameplate, and How Many Ways to a Kilowatt Hour Scavenger Hunt help to develop students' understanding of the units of electricity use and identifying appliances that use relatively large amounts of electricity. Resource page Annotated Real-time Electricity Use Display for Addison Fox Household can be used here to aid students in connecting patterns of use to displays. Introduce students to the Home Specification Sheet for Addison Fox for the purpose of stimulating thinking about other factors that contribute to the electricity use patterns they've been observing.*

Continue to share findings and direct students toward using real-time data and other available data to make recommendations for reducing electricity use and costs.

In addition to continuing their investigations, consider engaging students in the development of a checklist of actions people can take (or some other product that could be shared with a broader community) to reduce their electricity use and costs. Consult the *PowerSleuth* website (www.powersleuth.org) for example projects.

Extensions

Students may:

- **compare available real-time electricity data with Addison's.** Launch an inquiry using this data. Encourage families to contact their local utility company with regard to accessing real-time electricity data as smart meter deployment is completed.
- **determine a percentage of kW or money savings.** Example: If an individual wanted to save $X how many kWh would that be? What are some ways this could be done based on data? Calculate cost savings.
- **investigate Energy Star Labels. Students can investigate appliances with energy star labels and compare purchase prices and operating costs.** This is an extension of *Energy for Maine* Lesson 7: *Watt's in a Name(plate)?* Students can learn more about what information is found on energy star labels and how they can be used to make choices when purchasing appliances. Students can engage in calculations of pay back periods for Energy Star appliances or other devices (ex: CFLs).
- **conduct an inventory of household electronic devices. Students may find it useful to investigate the "always on" bar shown on the PowerMeter graph.** What devices contribute to this reading? Devise a strategy for inventorying room by room

what types of appliances might contribute to a home's constant use of electricity. Students can use the Resource Page *Home Specification Sheet for Addison Fox Household* as a model.

- **take part in an "Electricity and the Home" Scavenger Hunt.** Provide students with a list of electricity related items to find at their homes. As items are generated, be sensitive to socio-economic differences that may arise. Consider having students work in teams or small groups. Students can be asked to capture "proof" that they found the item by taking a photograph of it. Some examples of things students might find are their electric meter, electrical panel, circuit breaker, master emergency switch, electric bill, an electric device that is "always on," an "Energy Star" appliance, and so forth.