**Searching for Solutions: Using Electricity Data to Understand and Reduce Use**

**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 their 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 lesson plan is designed to help teachers facilitate student-centered investigations using real time electricity data from emerging monitoring devices (e.g. smart meters and The Energy Detectives or TEDs). 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 tells us are difficulties for middle schoolers. 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 and act responsibly in its energy use, it is critical that students’ educational experiences begin early and include first-hand experiences to help them develop an understanding of the electricity and, in this case, how their interactions with the phenomena impact the environment. In this lesson, students are acting 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 alongside their students – working to understand electricity and how it’s used and learning to explore how new technologies in electricity monitoring can help in making evidence-based decisions in developing 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 complete 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 of 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 that time however, this lesson plan temporarily uses an intermediate device, namely “The Energy Detective” or TED and Google PowerMeter ([www.google.com-powermeter](http://www.google.com/powermeter)) to access and share electricity data from the home for student investigations. How this technology gets set up and works to collect information about electricity use in the home is explained in detail at the Maine Mathematics and Science Alliance face-to-face workshops. For more information about TEDS, visit [www.theenergydetective.com](http://www.theenergydetective.com). Once smart meter deployment is complete this lesson plan will be updated.

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” power grid system, which has been virtually unchanged since it’s development in the early 20th century despite the explosion 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 at the proper voltage 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 this grid of power 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 this 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 also 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 at off peak hours (known as “time of use rates”). 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 its residential customers in their service areas but few customers have enrolled in these plans.

Despite the apparent benefits of smart metering technologies, people in Maine and elsewhere have raised concerns around 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](http://www.maine.gov/puc). Central Maine Power has compiled answers to the questions and concerns people have 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. This lesson plan is by design a framework for student-centered scientific investigations and allows for flexibility by offering a number of suggestions, options and scaffolded experiences for students. As teachers use this framework 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 students will need support in detecting trends in data and while middle school students can often compute statistical measures such as mean, median, mode, but their understanding of what these measures of central tendency tell us 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. Included in this lesson plan framework is a menu of exercises designed to specifically help students build understanding in these particularly challenging areas. 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, measured and compared.
* There are many questions that can be investigated using electricity data. Asking appropriate questions are key to driving scientific investigations.
* Ongoing investigations provide evidence for solving problems, including developing strategies for conserving electricity.

**Lesson Goals**

Students will :

* develop an understanding of and examine electricity use data.
* be able to 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 lesson and its menu of activities as there are several approaches outlined in supporting students as they work through investigations.
* Become familiar with the data students will access in this lesson.
* Determine what data will be used for the “Mystery” data and how students will access the data. This includes deciding which electricity bill(s) will be used in Step 1.
* Determine the platform students will use to share findings (electronic and/or face-to-face).

**Materials**

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| --- | --- |
| **Item** | **Quantity** |
| Scientist’s Notebook | 1 per student |
| Computer(s) LCD projector – for class use  | 1 per class minimally; and one per student if possible |
| Chart paper and markers | 1 per class |
| Index cards or chart paper cut into strips | 1 per pair/group |
| Teacher Resource 1: “Please answer my questions about electricity use” email | 1 per class |
| Teacher Resource 2: “Is this helpful? Meter readings?” email (optional)  | 1 per class |
| Teacher Resource 3: “Check this out – Google PowerMeter” email | 1 per class |
| Student Handout 1: Sample Electricity Bills (BH, CMP, MPS) | 1 per student or pair |
| Student Handout 2: How to Read Your Electric Meter | 1 per student or pair |
| Student Handout 3: Investigation Planning Guide | 1 per student or pair |

**Time Required**: 5-10 sessions\*

\*It is strongly recommended that the investigative sequence be repeated at least once more to provide students additional opportunities to practice and further develop their skills and refine their investigation.

**Connection to *Maine Learning Results (MLR), Benchmarks to Science Literacy (BSL),* and *National Science Education Standards (NSES)*:**

* 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
* Identify personal choices than can either positively or negatively impact society including population, ecosystem sustainability, personal health, and environmental quality. MLR C3 (6-8) b

**[ Forthcoming:** *Common Core State Standards for Mathematics* **]**

**Teaching the Lesson**

**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” (Teacher Resource 1). Provide students with a copy of Addison’s electricity bill (Student Handout 1). 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 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 students have finished sharing the information found on the bill, revisit Addison’s email to clarify the questions being asked. Write the questions on the board and 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 conversation that clarifies the questions being asked and discusses the differences in the questions being asked. Help students recognize that some of the questions Addison asks are 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 further 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 work toward developing 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 data and it is important to determine which pieces are relevant and which will help 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 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 the list of mini lessons and extensions found at the end of this lesson plan. This might also be an opportune time to work on developing students’ concept of a kilowatt hour (kWh) using activities described in mini lesson/extension list. 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 an answer 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 statistical analysis of monthly kWh (mean, median, and mode or 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 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. 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 $0.05981) bringing the total to $39.52. This amount is different from the total amount shown on the bill because there are additional charges from the utility for such things as providing the network for the electricity to get to your home. Electricity companies in Maine 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.*

[ 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 could be organized to work through the focus questions depending on the time available and class characteristics.

Option A: Small groups of (3-4) students could 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 could 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 taken, 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 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 (Teacher Resource 2). Clarifying what an electricity meter is, discuss where they are likely found, 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 electricity meters are read. Use Student Handout 2, developed by Maine Public Service <http://www.mainepublicservice.com/education/electricity-education.aspx>, to teach students how to read a meter. Encourage students to find their 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. (Option 1) Introduce real time data monitoring.** Share the message with the subject line “Check this out – Google PowerMeter” (Teacher Resource 3) with students. Provide students with access to Addison’s PowerMeter data. Remind students of the new questions posed:

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

As students examine the PowerMeter 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 and Google PowerMeter interface. 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 scale showing how many kW varies and 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 first briefly discuss in pairs what a response to Addison’s first two questions might include and then 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.

**5. (Option 2) Introduce real time data monitoring.** Share the message from Addison as described in Option 1. Provide students with Student Handout: PowerMeter Raw Data dated August 16, 2010 (or provide raw data of electricity use from another day/source. Helpful hints and tips for pulling together a different data set using the TEDs is included in the mini-lesson/extension section.)

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

* *What is this data? In other words, what is being observed or measured?*
* *How was it collected/recorded?* *(How was it generated?)*
* *Why is data often presented/displayed in tables?* *What is the purpose of a data table?*

Purpose of a data table is to provide information. Scientists in different fields collect data in many different 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 it is later displayed in a graphic form. Ask students why; there are a number of reasons. Data makes visualizing and interpreting easier and variation can be analyzed more readily in a graph.

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

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

The list 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)

Ask students to create a graph of the data in the data table\*. Have students work in pairs and do some initial brainstorming before they construct the graph of what they want the graph to show – what is the graph’s purpose? Said differently, students should consider what question the resulting graph would answer. What type of graph is appropriate? Line? Bar? Something else?

*Note: The data represents snapshots of use at particular times (10 minute intervals) during the day and is therefore recorded in kW. The data does 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 the Google PowerMeter displays use 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. One of the purposes of doing this graphing exercise is to help students better understand what the Google PowerMeter display is showing. Another way to make the graphing task more manageable would be 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. Have students discuss similarities and differences in their displays and discuss the strengths and weaknesses of the displays. Share with students the handout showing the Google PowerMeter display for August 16, 2010 and ask students to compare and contrast this to their graphs. As an extension, the discussion could segue into conversation about why they think Google made the decision to display the TED data the way they do – what question does it answer? There is also opportunity for students to see the same data graphed using different time intervals by sharing the 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. Could 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 talk to one another and come up with as many questions as they can about what they are noticing and wondering. 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. Allow students a few minutes to examine the PowerMeter display, discussing what they are wondering and crafting questions.

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 perhaps 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: At the time of this writing, investigable questions 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, at this time students’ investigation questions are limited to those that can be answered by the PowerMeter graphs only.*

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 \_\_\_? 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 slightly modifying them.

[ 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 that they will take action on. Have students revisit the list of investigable questions generated. Ask students to either place a check next to a question they find most interesting or ask students to writing 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 the top three questions get 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 Student Handout 3: 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 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.

**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. Ideally, students would share their findings via an electronic forum (i.e. Moodle, Study Wiz, Google Docs) and be asked to discuss and make comments about their peer’s work in this forum. Alternatively, hold a scientists’ meeting. Have each group present their findings to the class. Student presentations should be concise and should 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 and examine these questions with students; have students select another investigative question to answer following the steps outlined earlier. 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 could take (or some other product that could be shared with a broader community) to reduce their electricity use and costs.

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**Menu of Mini Lessons and Extensions**

In addition to the lessons in the PowerSleuth curriculum guide *Energy for Maine*, these optional supplementary mini lessons/extensions can be incorporated into this lesson plan as needed to build specific skills and knowledge, enrich and support learning.

**Mini Lessons**

**Predicting Energy Use by Sector.**  A modified version of a portion of Lesson 6 from *Energy for Maine* aimed at familiarizing students with the various ways energy is used by different groups called sectors. Students are asked to make a visual representation to make a prediction about percentage of energy use by sector. This exercise sets electricity use into the large context of energy use.

**Next Month’s Electricity Use.** Students are given monthly kilowatt hour data from Addison Fox’s home and asked to settle an argument between two friends about the best way to use the data should to make a prediction about next month’s use.

**Appliance Card Sort.** This set of appliance cards can be used to preassess students’ knowledge about “energy hogs,” and to engage students in research around the number of watts various appliances use. Additional teacher notes are included with the card set master.

**How Many Ways to a Kilowatt Hour? Scavenger Hunt.** This exercise helps students conceptualize how much electricity use is equivalent to 1 kilowatt hour (kWh). This activity could be one that students could do along with a parent.

**PowerMeter Raw Data.** Students determine how best to represent real-time electricity use from a raw data set. They compare and contrast their graph to those generated by others and to the PowerMeter display of the data set.

**Develop a Graph from a Narrative.** Students read a narrative description of electricity use and sketch a graph that they think would result from the activities outlined in the narrative. The idea is to have students focus on the shape of the graph and not be overly concerned with the graphing conventions. Once students have constructed their graphs, engage in a class discussion. Ask students how they showed high amounts of electricity use, low amounts of electricity use, constant electricity use, sharp changes in electricity use, and so on. Consider making a class list of the descriptive words students generate.

**Developing a Narrative from a Graph.** Students create a narrative description to match a PowerMeter. graph.

**Graph Match.** Students match PowerMeter graphs to descriptions of electricity use.

**Making a Statement.** Students are given PowerMeter graphs and a series of statements. Students discuss each statement, one at a time, with a partner to determine whether or not the statement can be made about the graph set.

**Annotated PowerMeter Display for Addison Fox.**  This handout shows the PowerMeter display and describes the electricity used in the home at the time the display was generated. Use this handout to help students connect patterns of use to displays.

**Two Views, Same Data.** This handout shows two PowerMeter displays for the same day and time period. One display is generated from 1 hour intervals and is currently how electricity use is displayed from Bangor Hydroelectric and the other is the 10-minute TED PowerMeter display. Discuss with students the similarities and differences/advantages and limitations of the two views.

The following exercises were developed by Mary Theberge Mt. Ararat Middle School, Topsham, ME

**Electrical Use/Cost Worksheet 1.** Students working in pairs construct a bar graph of kilowatt hours used per month and a line graph of costs versus kilowatt hours used. They answer questions using the graphs and discuss the types of questions that can be and can’t be answered by each of the graphs.

**Electricity Delivery Cost Rate of Change Worksheet.** In this exercise, students explore the rate of change of cost per kilowatt hour.

**Total Cost of Electricity (Delivery and Supply).** Students explore the pricing structure for electricity (delivery and supply costs).

**Comparison of Delivery Costs and Total Cost Graphs.** Students make line graphs using the same axes of the (1) delivery costs versus kilowatt hours used and (2) total costs versus kilowatt hours used. They compare the similarities and differences of the two graphs and investigate slope.

**Electricity Cost Rate versus Rate of Change.** Students calculate the difference between cost per kilowatt rate and the rate of change in the cost using a table.

**Student’s Family Use Recording Sheet.** Students record the appliances and other electrical items that use electricity in their homes noting who uses the item and the time of day the items was used.

**What Would Your Goggle PowerMeter Graph Look Like?** Students make a sketch of what they think their powermeter graphs would look like over the course of a week. They write a description of the events in their homes that produced the graph they drew.

**Extensions**

**Comparison data.** Compare available real-time electricity data with Addison’s. Launch inquiry using this data. Families in the Bangor Hydro Electric service area have access to smart meter data.

**Calculating costs.** 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? 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 could 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 when investigating 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.

**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 socioeconomic differences that may arise. Consider having students work in teams or small groups. Students could be asked to capture “proof” that they found the item by taking a photograph of it. Some examples of things students could 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.

**References and Resources**

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