How Happy are You and Your Family with the Electricity Bill?

A grade 7-8 science (physics) module on determining energy consumption at home

Abstract

This module leads to a decision making activity, designed to consolidate learning about consuming energy, and energy saving, taking examples from everyday life and to introduce the concept of power. It involves the reading of an electricity bill and checking that the calculation of the bill is correct. It introduces students to the (kilo) watt as a unit of power and the kilowatt hour as the unit used in the home for energy consumption.

Sections included		
1.	Student activities (for students)	Describes the scenario in more detail and the tasks the students should perform
2.	Teaching guide	Suggests a teaching approach
3.	Assessment	Gives suggested formative assessment strategies
4.	Teacher notes	Gives expectations of calculations to be carried out by students

Acknowledgement

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Overall Objectives/Competencies: The students are expected to:

- Decide, with justification, how best to produce a balanced electricity bill.
- Designing a questionnaire (as a research process) to obtain data on the major costs on electricity bills and how to present the results in a tabular form / diagrams.
- Cooperating as member of a group in designing and carrying out an investigation project.
- Explaining the meaning of power when used for electrical appliances, rather than mechanical machines, and the units used to measure power.
- Determining the relationship between power and energy and be able to calculate energy consumption knowing the power of an appliance.

Curriculum content: power as (kilo)watts, energy as kilowatt hour,

Kind of activity: Designing a questionnaire, calculations involving (kilo)watts ad kilowatt hours, decision making discussion on realistic ways to reduce the electricity bill.

Anticipated time: 4 lessons

This unique teaching-learning material is intended to guide the teacher towards promoting students' scientific literacy by recognising learning in 4 domains – intellectual development, the process and nature of science, personal development and social development.

Its uniqueness extends to an approach to science lessons which is designed to follow a 3 stage model. For this the approach is intentionally from society to science and attempts to specifically meet student learning needs.
This uniqueness is specifically exhibited by:

1. a motivational, society-related and issue-based title (supported in the student guide by a motivational, socio-scientific, real life scenario);
2. forming a bridge from the scenario to the scientific learning to be undertaken;
3. student-centred emphasis on scientific problem solving, encompassing the learning of a range of educational and scientific goals;
4. utilising the new science by including in socio-scientific decision making to relate the science acquired to societal needs for responsible citizenship

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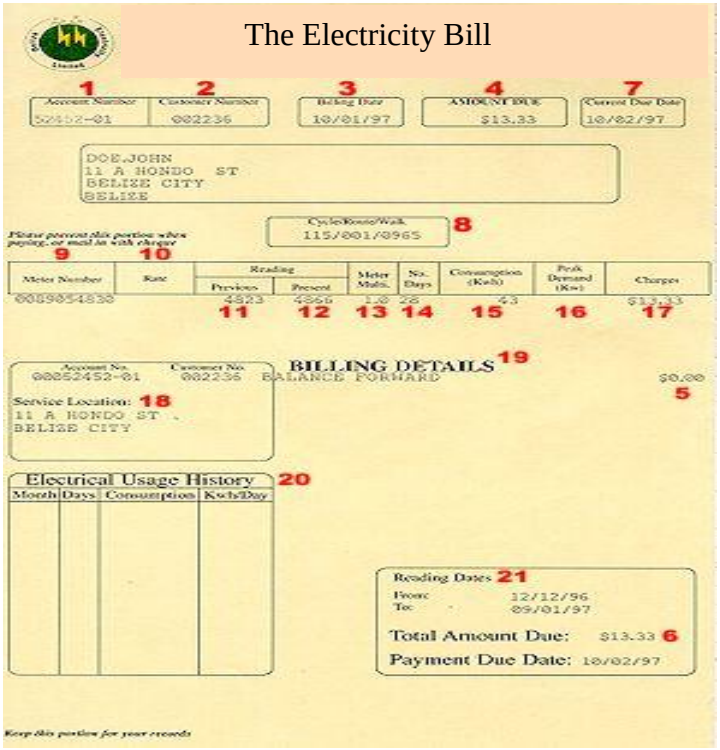
How Happy are You and Your Family with the Electricity Bill?

Student Activities

The Scenario

Today, thanks to technological achievements, more and more equipment needs electric power to operate. Think what would happen if there was a black-out right now! What would be out of action? Unfortunately, as a result of the heavy use of electrical devices, the household electricity bill has become an important part of the family budget. But are you happy with this? Would you be interested in influencing the members of your family to see how it might be possible to reduce this bill? What devices are large users of electricity? Are they essential?

Below is an example of an Electricity Bill:



Your Task

Within the whole Class:

1. Discuss/compare different electricity bills and find out which parameters/factors contribute to the total amount paid. Mention which of them are “internal” (from the family) and which are “external” (from the state).
2. Discuss the questions that will be included to create a questionnaire for the proposed research to find out which appliances are used I the home and for how often.

In Groups:

1. Each group is required to put forward 5 questions in a short time.
2. Discuss the questions and from the sources create a common questionnaire.
3. Each member of the group takes the responsibility to give the questionnaire to her/his family, plus one more family and bring responses to the next class.
4. Decide the selection of different electrical equipment for each group to study power, energy transformation and energy consumption in a period of time.
5. Design and carry out an experimental investigation to determine the consumption of each equipment selected.

In Groups:

1. Look over a part of the completed questionnaire (2 – 3 questions per group) and present the outcomes in bar diagrams or tables.
2. Prepare a presentation of the experimental results (measurements, calculations, etc).
3. Discussion and presentation of the conclusions of the equipment studied.

As a Class:

1. Presentation, discussion and comparison of each group’s outcomes.
2. Reach final conclusions on:
   How it might be possible to reduce the electricity Bill.
   What is meant by power and how important is it to be aware of this in determining items to reduce on the electricity bill?
   Protecting the environment (power stations, fuels needed)
   Effect on the State budget (fuels imported)
3. Discuss whether people are generally happy with their electricity bills or whether they would welcome guidance on how to reduce the bills (bearing in mind the percentage reduction you might be able to put forward) and determine certain ideas as proposals in order to change habits on consuming electric energy.

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Teaching guide

The activity relates to:

- Reinforcing an appreciation of the electric energy demands in every day life
- Being familiar with electrical energy consumption in a house
- Educating energy – conscious citizens
- Introducing the concept of power

Lesson Learning Outcomes

Lesson 1

At the end of this lesson, students are expected to be able to:

- Look at an electricity bill
- Devise a questionnaire

Lesson 2

At the end of this lesson, students are expected to be able to:

- Analyse the questionnaire
- Determine appliances using most electricity
- Determine appliances used the most
- Read the electricity meter

Lesson 3

At the end of this lesson, students are expected to be able to:

- Understand the meaning of power and its units
- Understand the meaning of energy and its units
- Determining appliances that use much power

Lesson 4

At the end of this lesson, students are expected to be able to:
Reach a justified decision whether the household is happy with its electricity bill

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Suggested Teaching Strategy

1. The lesson starts from the scenario and by brainstorming ideas by students
2. Students are divided into groups to plan the development of their project
3. While discussing the questionnaire design, students are guided to include questions such as the following, in order to cover all the mentioned objectives:
   - How many and who are the members of the family (adults / children)
   - Time spent at home
   - Use of electric boiler, air-conditioner, etc Are they operating when no-one is at home?
   - Coffee machine: how many hours is it on during the day?
   - When you are on vacation do you turn off the T.V. completely?
   - Do you forget the lights are on and leave them on even when there is no-one in the room?
   - How often do you make use of the washing machine and the electrical iron?
   - What do you think: saving electric energy at home plays a role in the protection of the environment ?
4. During the selection of the equipment by each group, students are guided to make sure there are different ones by considering the power ratings of the equipment. The teacher introduces the units of power and allows the students to undertake a series of exercises to ensure they understand the meaning of pwer and the units used.
   a. Every group plans its own project according to the given Students' Guide
   6. Discuss as a class about questions so as to develop the final form of the questionnaire
5. The teacher arranged for the completed questionnaires to be distributed, then discussed in groups and the findings are analysed and presented
6. Each group presents the investigation results and calculations to the class
7. The teacher guides the discussion of the outcomes from each group; as a class the students conclude, propose and finally decide about:
   - reducing electric energy consumption in a family and at state level (giving special attention to power ratings)
   - informing the members of their family about these matters
   - highlighting the environmental protection

Achieving the competencies

Competency	To be achieved by
1 Decide, with justification, how to have a balanced electricity bill	Discussing within the group and recording the decision so as to present to the rest of the class
2 Designing a questionnaire (as a research process) to obtain data on the major costs on electricity bills	Students create the questionnaire as a group and administer it to families
3. Communicating by presenting the results in a tabular form / diagrams	Students draw their own diagrams, take part in the oral discussions and record justifications for decisions
4 Cooperating as member of a group carrying out an investigation project	Students cooperate in the group in carry out the project and in making the decisions
5 Explaining the meaning of power when used for electrical appliances, rather than mechanical machines, and the units used to measure power	Students undertake to complete a written record to explain the meaning of power
6 Determining the relationship between power and energy and be able to calculate energy consumption knowing the power of an appliance	Undertaking calculations of the electricity consumed by various appliances in the home

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Suggested Assessment

This guide to assessment strategies is put forward from different perspectives. In part A the assessment is based on the skill to be developed in the student. Part B is based on the assessment strategies to use in each lesson, whereas part C illustrates the assessment by the 3 different approaches which a teacher may use for formative assessment – observation, by oral communication, or by marking of written work. Summative assessment strategies are not shown, but these could relate to viva type oral communication and/or to the marking of written tests/examination questions.

Part A Assessment based on Skills Attained

Able to award a social values grade (objective 1).

Teachers listens to the discussions within the groups and the presentations to the class

x Not able to contribute to the discussion in a meaningful way

√ Participates in the discussion and is able to record the decision and the justification for this

√√ Not only participates in the discussion and puts forward a point of view but is able to do this with persuasion and can offer counter-arguments to points made by others.

Able to award a science method grade (objective 2).

The teacher marks the student questionnaires before the students to collect data for the community

x Not able to suggest appropriate items for the questionnaire.

√ Able to suggest items for the questionnaire and to put these into a useful sequence. Able to use the questionnaire to collect relevant data.

√√ Able to suggest key items for the questionnaire which are suitable and relevant for the community and is able to put forward a sampling plan that reflects the need for sampling of the community for a fair result.

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Able to award a personal skills grade (objectives 3 and 4).
Teacher observes the students during the group work

x Does not cooperate with others during the group discussions and activities.

√ Participates in group work meaningfully, in the discussions and in the devising of questionnaires and recording of work in written form.

√√ Not only participates in the group work and in the discussions and written work, but takes on a leadership role helping others to participate.

Able to award a science concept grade (objectives 5, and 6).

x Not able to explain the meaning of power, the relationship between power and energy and the mechanism for calculating electricity used in the home

√ Able to explain the meaning of power and the relationship between power and energy with the help of the teacher. Able to read an electricity bill and determine the energy used.

√√ Able to fully understand and record in a meaningful way, the meaning of power and its links to energy. Able to read the electricity bill. Can deduce appliances that have been in great use.

Part B Assessed by Lesson

Lesson 1

	Dimension	**Criteria for evaluation The student:**	**Mark/grade given (x,√,√√)**
1	Creates a questionnaire	Puts forward appropriate questions for a questionnaire to find out what appliances are used in the home and how much electricity is used per month.	
		Creates an appropriate questionnaire to the level of detail required by the teacher.	
		Develops an appropriate procedure to collect data using their questionnaire	
2	Interpret an electricity bill	Looks at an electricity bill and able to understand the data given in the various columns	
		Draws appropriate conclusions related to the electricity used	

Lesson 2

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Interpret or calculate from data collected and making conclusions	Interprets data collected in a justifiable manner including the use of appropriate graphs, tables and symbols.	
		Draws appropriate conclusions related to appliances using the most electricity.	
		Draws appropriate conclusions related to the appliances used most frequently.	
2	Answers questions	Provides correct written answers to questions asked by the teacher on their manner of interpretation and drawing conclusions.	
3	Draws charts/tables.	Able to present findings in an appropriate graphical representation.	
		Able to present graphical representations in suitable detail.	
		Able to provide full and appropriate headings for charts, tables.	

Lesson 3

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Explanations	Able to explain the meaning of power and the units used.	
		Able to explain the meaning of energy and the units used.	
2	Interpret from data collected and drawing conclusions.	Interprets from the data collected those appliances which use much power compared with other appliances.	
		Draws appropriate conclusions related to the use of such appliances.	

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Lesson 4

	Dimension	Criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	Scientific or socio-scientific reasoning	Able to work cooperative with others in the group and consider the data obtained and other factors.	
		Gives a justified socio-scientific decision based on efficiency and other factors whether families should be happy with their electricity bill.	

Part C Assessment based on Teacher Strategy

Assessment Tool based on the Teacher's Marking of Written Material

	Dimension	Criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	Writes a plan or report of an investigation	Puts forward an appropriate research/ scientific question and/or knows the purpose of the investigation/ experiment	
		Creates an appropriate investigation or experimental plan to the level of detail required by the teacher	
		Puts forward an appropriate prediction/hypotheses	
		Develops an appropriate procedure (including apparatus/chemicals required and safety procedures required) and indicates variables to control	
2	Record experimental data collected	Makes and Records observations/data collected appropriately (in terms of numbers of observations deemed acceptable/accuracy recorded/errors given)	

3	Interpret or calculate from data collected and making conclusions	Interprets data collected in a justifiable manner including the use of appropriate graphs, tables and symbols	
		Draws appropriate conclusions related to the research/scientific question	
4	Answers questions	Provides correct written answers to questions given orally or in written format	
		Provides answers in sufficient detail especially when called upon to give an opinion or decision	
5	Draws charts/ diagrams/tables/ models/symbolic representations.	Able to provide graphical representation as required	
		Able to present graphical representations of a suitable size and in suitable detail	
		Able to provide full and appropriate headings for diagrams, figures, tables	
6	Scientific or socio-scientific reasoning	Illustrates creative thinking/procedures in solving problems	
		Gives a justified socio-scientific decision to an issue or concern, correctly highlighting the scientific component	

Assessment Tool based on the Teacher's Observations

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Functioning in the group during experimentation or discussion	Contributes to the group discussion during the inquiry phases (raising questions, planning investigation/experiment, putting forward hypotheses/predictions, analyzing data, drawing conclusions, making justified decisions).	
		Cooperates with others in a group and fully participates in the work of the group.	

		Illustrates leadership skills – guiding the group by thinking creatively and helping those needing assistance (cognitive or psychomotor); summarising outcomes.	
		Shows tolerance with, and gives encouragement to, the group members.	
2	Performing the investigation or experiment	Understands the objectives of the investigation/experimental work and knows which tests and measurements to perform.	
		Performs the investigation/experiment according to the instructions/plan created.	
		Uses lab tools and the measurement equipment in a safe and appropriate manner.	
		Behaves in a safe manner with respect to him/herself and to others.	
		Maintains an orderly and clean work table.	
3	Presenting the investigation or experiment orally	Presents the activity in a clear and practical manner with justified decisions.	
		Presents by illustrating knowledge and understanding of the subject.	
		Uses precise and appropriate scientific terms and language.	
		Presents with clarity and confidence using an audible voice.	

Assessment Tool based on the Teacher's Oral Questioning

	Dimension	**Criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Questions to individuals in a Whole Class setting	Answers questions at an appropriate cognitive level using appropriate scientific language	
		Shows interest and a willingness to answer	
		Willing and able to challenge/support answers by others, as appropriate	

2	Questions to the group	Able to explain the work of the group and the actions undertaken by each member	
		Understands and can explain the science involved using appropriate language	
		Willing to support other members in the group in giving answers when required	
		Thinks in a creative manner, exhibits vision and can make justified decisions	
3	Questions to individuals in the group	Able to explain the work of the group and actions taken by each member	
		Understands the purpose of the work and shows knowledge and understanding of the subject using appropriate scientific language	
		Can exhibit non-verbal activity (demonstrate) in response to the teacher's questions, as appropriate	

How Happy are You and Your Family with the Electricity Bill?

Teacher Notes

- It is useful to collect electricity bills (at least 4) from households of one and four persons, with at least one for the winter period and another for a summer period.
- It is useful to have on display different equipment that need electric power to function. (e.g. T.V., iron, electric boiler, computer, electric oven, lights) (Alternatively students can check these apparatus at home, when parents can guide them to find the labelling indicate power consumption).
- Access to an electricity meter (this could be by means of a video/CD)

Student Handout

The following steps /questions are to help you to complete your project successfully:

1. Which criteria will you choose for selecting the house equipment ?
2. Are you sure that you are measuring the consumption of only one piece of equipment at a time? How do you determine this?
3. Measure, for a time duration of 5 minutes, the energy consumption of each equipment on the house electric meter.
4. Notice the units which are used to measure energy.
5. Calculate the energy consumption using the theoretic type (find it in your textbook), for the same equipment and the same period of time. Use the prospectus of the equipment for the power, etc. NOTICE: This step is omitted in the first grades.
6. Calculate the amount of money needed to be paid the consumption for each equipment
7. Which of the equipment consume more and which the less?
8. What is the energy transformation for each piece of equipment?
9. Is there a connection between the energy transformation taking place and the consumption?

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Student Handout 2

Exercise to Aid the Understanding of the Concept of Power

Answer the following:

1. On which of the following does the electricity we consume depends ? (there may be more than one correct response)
   (a) the voltage of the appliance;
   (b) the size of the appliance;
   (c) the type of plug used;
   (d) the current supplied to the appliance;
   (e) how long the appliance is in use;
   (f) the age of the appliance.

2. For each of those selected in question 1, give the name of the units in which it is measured, both as (a) the base unit and (b) when multiplied by 1000.
3. Look at the information supplied on an electrical appliance. Which of the units given in question 2 are observed ?
4. As the manufacturer of the appliance does not know when, where or how long the appliance will be used, it can only indicate the power of the appliance. What units (by deduction or otherwise) represent the power of the appliance ?
5. Link the units of power to the other units indicated in question 2.
6. If an appliance is plugged into the usual mains supply and had a rating of 0.25 amps, what power rating would you see written on the appliance ?
7. If the power rating was given as 10 watts, what was the current drawn when the appliance was plugged into the mains supply ?
8. The electricity meter needs to record the power of the appliance and the time for which it is used. What units does it use to do this ? What are the units of electricity consumed which are written on the electricity bill ?

Explanation of the numbers on the electricity bill

1. Your **ACCOUNT NUMBER** is a unique number that identifies the location of the place where you are consuming electricity.

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2. CUSTOMER NUMBER: This is a unique number assigned to each customer. A customer may have more than one account number, but an account can have only one customer number. Your customer number will never change.

3. BILLING DATE: This is the date that the bill is prepared and sent out to you

4. TOTAL AMOUNT DUE

5. ARREARS OVER DUE are the previous months' charges which have not yet been paid.

6. CURRENT AMOUNT DUE is the total of electricity charges for current period consumption

7. CURRENT AMOUNT DUE DATE is the latest date on which the Current Amount Due should be paid in order to avoid disconnection

8. The **CYCLE/ROUTE/WALK** is a numbering sequence used to assist BEL in locating the address where electricity is being consumed.

9. METER NUMBER is a unique number used to identify each meter.

10. RATE is the charge per unit of electricity consumed.

11. PREVIOUS READING is the reading on your meter when it was read in the second to last reading period.

12. PRESENT READING is the reading on the meter when it was read in the last reading period.

13. The **METER MULTIPLIER** (shortened 'METER MULTI') is a factor used to arrive at actual consumption when calculating consumption of large customers.

14. NO. DAYS is the number of days over which current consumption is metered.

15. CONSUMPTION is the actual consumption of electricity for the period and is calculated as (present - previous) x meter multiplier.

16. PEAK DEMAND is the largest amount of electrical power utilized at any point in time during the current period.

17. CHARGES are the charges for electricity consumed during the current period and is calculated by multiplying Rate by Consumption.

18. SERVICE LOCATION is the address of the location where you are consuming electricity. This may therefore be different from your mailing address.

19. BILLING DETAILS give a summary of charges, other than those for current electricity consumption, which are included in the Current Amount Due.

20. ELECTRICAL USAGE HISTORY gives a rolling 12-month summary of electricity consumed. Customers can use this to better understand how the

21. **READING DATES** are the last and second to last dates on which the meter for the customer's account was read. These dates will coincide with the present and previous readings.

Watt

The watt (symbol: W) is the SI derived unit of power, equal to one joule of energy per second.

A human climbing a flight of stairs is doing work at the rate of about 200 watts. A first class athlete can work at 375 watts for 30 minutes before exhaustion. An automobile engine produces mechanical energy at a rate of 25,000 watts (approximately 30 horsepower) while cruising. A typical household incandescent light bulb uses electrical energy at a rate of 40 to 100 watts, while the energy-saving compact fluorescent lights which are replacing them use 8 to 20 watts to yield the same light output.

Definition

One watt is one joule (the SI unit of energy) per second, that is 1 newton metre per second. It may be visualized simply as the amount of energy expended by a single candle.

$$1\ \mathrm{W} = 1\ \frac{\mathrm{J}}{\mathrm{s}} = 1\ \frac{\mathrm{kg}\cdot\mathrm{m}^2}{\mathrm{s}^3} = 1\frac{\mathrm{N}\cdot\mathrm{m}}{\mathrm{s}}.$$

In electrical terms, it follows that:

$$1\mathrm{W} = 1\mathrm{V}\cdot 1\mathrm{A}.$$

That is, if 1 volt of potential difference is applied to a resistive load and a current of 1 ampere flows, then 1 watt of power is dissipated.[2]

Origin and adoption as an SI unit

The **watt** is named after James Watt for his contributions to the development of the steam engine, and was adopted by the Second Congress of the British Association for the Advancement of Science in 1889 and by the 11th General Conference on Weights and Measures in 1960 as the unit of power incorporated in the International System of Units (or "SI").

Confusion of watts and watt-hours

Power and energy are frequently confused in the general media, for instance when a device is said to be rated at "100 watts per hour", which does not make any sense since a watt is a rate of doing work or using energy of 1 joule of energy per second. As a rate itself, a watt does not need to be followed by a time designation, unless one is talking about a change in power over time, analogous to an acceleration or deceleration.

Because a joule as a quantity of energy does not have a readily-imagined size to the layperson, the non-SI unit watt-hour, or rather its multiple the kilowatt-hour, is frequently used as a unit of energy, especially by energy-supply companies (electricity and natural gas suppliers) which often quote charges by the kilowatt-hour. A kilowatt-hour is the amount of energy equivalent to a power of 1 kilowatt running for 1 hour (3.6 MJ).

The watt-hour (symbol W·h or Wh) is a unit of energy. It is most commonly used on household electricity meters in the form of the kilowatt-hour (kW·h or kWh), which is 1,000 watt-hours. It is not used in the International System of Units (SI), despite being based on the watt, as the hour is not an SI unit. The SI unit of energy is the joule (J), equal to one watt-second. It is, however, a commonly used unit, especially for measuring electric energy.

1 watt-hour is equivalent to 3,600 joules (1 W x 3600 s), the joule being the canonical SI unit of energy. Thus a kilowatt-hour is 3,600,000 joules or 3.6 megajoules.

Pricing for kilowatt-hours

Power companies sell energy in units of kilowatt-hours. In general, energy (E) is equivalent to power (P) multiplied by time (t). To determine E in kilowatt-hours, P must be expressed in kilowatts and t must be expressed in hours. Suppose a 1.5-kW electric heater runs for 3 h. Then P = 1.5 and t = 3, so the energy E in kilowatt-hours is: E = Pt = 1.5 x 3 = 4.5 kWh If P and t are not specified in kilowatts and hours respectively, then they must be converted to those units before determining E in kilowatt-hours. Consider a set-up with one 100 W light bulb (0.1 kW) left on for 10 hours per day. This will consume 1 kilowatt-hour per day (0.1 kW x 10 h). If a power company charges $0.10/kW·h, then this light bulb will cost $0.70 to operate over the course of a week (0.1 kW x 10 h x $0.10/kW·h x 7 days in a week) (see unit juggling for more information).

Conversions

from / to	Joule	Watt-hour	Electronvolt	Calorie
1 J = 1 kg m^2	1	0.278×10^{-3}	6.241×10^{18}	0.239
1 W·h =	3600	1	2.247×10^{22}	859.8
1 eV =	$1.602 \times$	4.45×10^{-23}	1	3.827×10^{-20}
1 cal =	4.1868	1.163×10^{-3}	2.613×10^{19}	1

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