TSC-4061-2

THE ENERGY CHALLENGE

sofad

PERIODIC TABLE OF THE ELEMENTS

Atomic number: 1 — Symbol: H — Hydrogen — Atomic mass: 1.008

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H Hydrogen 1.008																	2 He Helium 4.003
2	3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
3	11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulphur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.63	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.96	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.904	54 Xe Xenon 131.293
6	55 Cs Cesium 132.905	56 Ba Barium 137.327		72 Hf Hafnium 178.49	73 Ta Tantalium 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)		104 Rf Rutherfordium (267)	105 Db Dubnium (268)	106 Sg Seaborgium (271)	107 Bh Bohrium (272)	108 Hs Hassium (270)	109 Mt Meitnerium (276)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (280)	112 Cn Copernicium (285)	113 Uut (Ununtrium) (284)	114 Fl Flerovium (289)	115 Uup (Ununpentium) (288)	116 Lv Livermorium (293)	117 Uus (Ununseptium) (294)	118 Uuo (Ununoctium) (294)

57 La Lanthanium 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.054	71 Lu Lutecium 174.967
89 Ac Actinium (227)	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

State at 25°C:
(Symbol colour)

Solid

Liquid

Gaseous

Metals | Metalloids | Non-metals

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Learning Guide

sofad

The Energy Challenge

This learning guide was produced by the Société de formation à distance des commissions scolaires du Québec (SOFAD).

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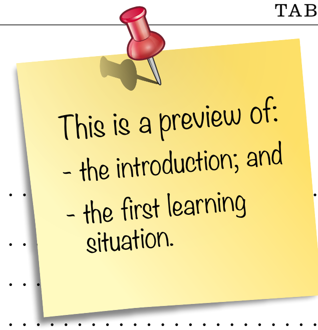
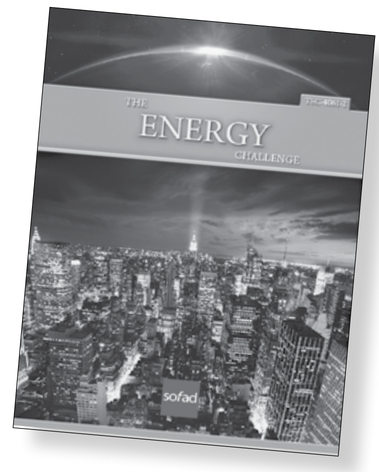


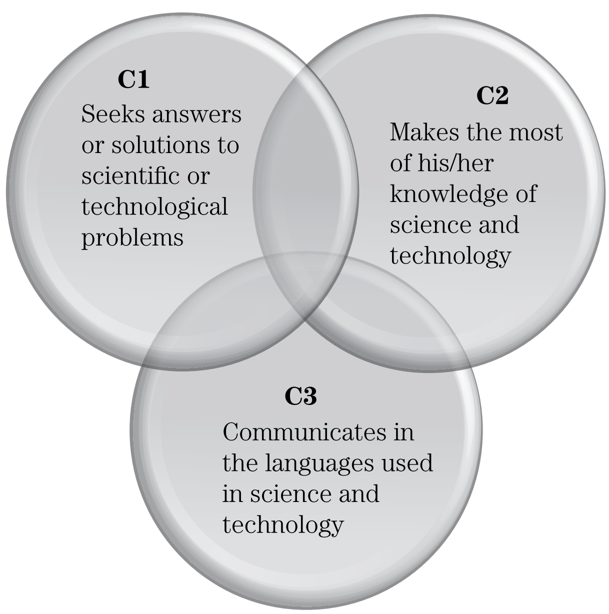
Introduction



Welcome to *The Energy Challenge* course. Electricity plays a major role and in our daily lives; it is quite simply indispensable. For instance, a power failure can completely upend our daily routine and a run-down cell phone battery means that we are cut off from others. In this course, you will learn about the basic concepts of electricity and magnetism.

What is electricity? How is it produced? What happens when we plug in an appliance or when we use a battery to power our laptop? Electricity is the result of a transformation of energy. This course focuses on the transfer, transformation and use of energy. Our society relies on hydroelectricity as its main energy source. What are the physical phenomena that underlie the operation of a hydroelectric generating plant? Are there other ways to produce electricity? How do the various technologies designed to harness this resource affect our environment? It is often said that the cheapest and cleanest energy is the one that we save. Are we aware, as individuals and as a society, of the economic and environmental consequences of our daily energy consumption habits?

In this course, you will study issues and technological applications that centre on a common theme: the energy challenge. Beyond the simple acquisition of knowledge, however, you will also develop three subject-specific competencies (C).



You will develop these competencies by carrying out tasks that are part of complex learning situations. Here are some examples. For C1, you will design a doorbell and an alarm system. For C2, you will assemble and analyze electrical circuits. For each of these two competencies, you will apply C3, by explaining your results and justifying your choices. For example, you will give your opinion on the hydroelectric system used in Québec, by taking into account the environmental impact of this type of energy production. These competencies will also be developed in the evaluation activities (three scored activities and one self-evaluation activity) designed to help you assess your progress in the course.

Areas of Knowledge

The knolwedge you will acquire in this course can be divided into three main areas: Earth and Space, the Technological World and the Material World. Earth and Space focuses on the various technological methods used by humans to produce electricity from the energy sources found in the lithosphere, the hydrosphere and the atmosphere, and the effects of these methods on the environment and human health. Solar energy and tidal energy are also examined as sources of electrical energy. The Technological World focuses on basic concepts relating to the design and analysis of electrical circuits, as well as the symbols used to represent circuit components and connections. Lastly, the Material World focuses on the organization of matter and the periodic table, the electrical and magnetic properties of matter, and the energy transformations that occur within a system. The table on the next page presents the concepts to be acquired in the seven learning sequences of the guide and the corresponding areas of knowledge.

Essential knowledge and the areas of knowledge

Learning sequence	Essential knowledge	Earth and space	The techno-logical world	The material world
❶ My Energy Needs and Energy Sources	Energy resources	√		
	Transformation of energy		√	
❷ Electrostatics	Rutherford atomic model			√
	Subatomic particles			√
	Electrical field			√
	Coulomb's law			√
	Electrical charge			√
	Standards and representations		√	
❸ Electrokinetics	Electrical circuits			√
	Ohm's law			√
	Electrical field			√
	Minerals	√		
	Conduction, insulation, protection		√	
	Controls		√	
	Standards and representations		√	
❹ Electrical Circuits	Electrical circuits			√
	Ohm's law			√
	Kirchhoff's laws			√
	Standards and representations		√	
❺ Magnetism and Electromagnetism	Forces of attraction and repulsion			√
	Magnetic field (of a live wire)			√
	Electromagnetic induction			√
	Magnetic field of a solenoid			√
	Standards and representations		√	
❻ Sources and Uses of Electrical Energy	Relationship between power and electrical energy			√
	Energy resources	√		
	Solar energy flow	√		
	Earth-Moon system	√		
	Transformation of energy		√	
	Standards and representations		√	
❼ Hydroelectricity	Energy resources	√		
	Transformation of energy		√	

Organization and Use of the Guide

This learning guide is organized according to the main characteristics of individualized learning and the principles of learning through concrete and realistic situations. It can be used by both distance education students and students in the classroom.

This approach is designed to:

- make you as active a participant as possible,
- make you responsible for your own learning,
- accommodate your personal work pace,
- allow you to make the most of your experience and knowledge.

As you work through the course, you will be able to recognize your successes and failures, determine the reasons for them and identify what you can do to continue learning. Whether you are taking this course at an education centre or as part of distance education, your instructor or tutor will be available throughout the course to support you and answer any questions you may have. If you find a particular topic especially difficult, don’t hesitate to ask him or her for help. Your instructor or tutor will be glad to provide you with invaluable advice, guidance and tips that will help you succeed in this course.

The learning sequences (LS)

In all, there are seven learning sequences (LS) which will help you acquire new knowledge and apply it competently. Each LS is organized in the same way: an introduction sets out the topic of the learning sequence, followed by an exploration activity which will allow you to test your knowledge of concepts that will be useful in carrying out the LS and by a series of four types of activities:

Knowledge acquisition activity

Discovery-based activity

Experimental activity

Expertise-based activity

The knowledge acquisition activity focuses on the discovery of new knowledge, whereas the focus of the other three activities is to help you develop your competencies by working on more complex tasks. In the experimental activity and the discovery-based activities you will carry out a task intended to help you develop primarily competency C1. The task you will carry out in the expertise-based activity will help you develop primarily competency C2. Competency C3 will be developed in all of the above activities.

Throughout the activities, you will be asked to answer questions that will aid in new knowledge acquisition and competency development. While at first you may not be able to answer all of these questions, you should nonetheless try to find satisfactory answers. The answers and related explanations are given immediately after. It is important that you try to understand all of the new concepts that are explained to you.

At the end of each LS is a series of integration exercises dealing with all of the concepts studied in the sequence as well as a summary of new knowledge, which will help you test your understanding of the subject matter.

Self-evaluation

Like the certification examination (i.e., the final exam), the self-evaluation activity consists of two sections to help you better prepare for the exam. Before you do this activity, take the time to read the list of new knowledge found at the end of each learning sequence, then refer to the table of new knowledge by sequence on page 9 of this introduction. Complete the self-evaluation activity without referring to the learning guide or the answer key. Then, complete the self-evaluation chart in order to assess what you have learned, and compare your answers with those in the answer key. If you feel you need to review parts of the course, follow the indications on the concepts to be reviewed that are given in the self-evaluation chart.

Answer Key

The Answer Key for the exercises in the guide is found after the self-evaluation activity and the conclusion. Refer to it after each set of exercises to make sure you have fully understood all of the concepts, before continuing the activity or going on to the next learning sequence. The answer key also includes the answers to the questions in the self-evaluation activity.

Glossary

The glossary at the end of the guide gives the definitions of the terms with dotted underlining that are found in the learning sequences. These terms are listed in alphabetical order. Don’t hesitate to refer to the glossary to help you better understand the terms you encounter in the guide.

Appendices

The appendices contain useful information and review prerequisite knowledge.

Scored Activities

The *Energy Challenge* guide is accompanied by three scored activities in separate booklets, one of which consists of an experimental activity. You will have to complete a scored activity after LS 3, LS 4 and LS 7. A reminder to this effect is included at the end of each of these learning sequences. The scored activities serve as an aid to learning; in addition to explicitly evaluating knowledge acquisition, each one includes a complex and meaningful learning situation designed to assess your ability to deal with these situations. You will also have to complete a chart in order to review the competencies you developed throughout the course. You will give this feedback at the end of each scored activity so that your instructor or tutor can assess your progress.

The scored activities are an integral part of the learning sequences and are not optional; you are required to do them whether you are a distance education student or attend an adult education centre. They will be corrected by your tutor if you are a distance education student or by your instructor if you attend an education centre. Send them to him or her once you have completed them.

You can purchase the booklets at a low cost or you can download them from the following address, under "Diversified Basic Education": *http://cours1.sofad.qc.ca/ressources*.

Evaluation for Certification Purposes

In order to earn the 2 credits for this course, you must obtain a mark of at least 60% on the final examination that will be held in an adult education centre. To be able to write this examination, you should have an average of at least 60% on the scored activities that accompany this guide.

The final examination for *The Energy Challenge* course has two sections, one practical and the other theoretical. These two sections are administered in two different sessions of 120 minutes each.

The practical part is based on a realistic application situation and consists of tasks to be carried out in the laboratory. The theoretical part consists of the following two sections.

The "Explicit Evaluation of Knowledge" section consists of short-answer and essay-type questions related to the definition and explanation of concepts and techniques.

The "Evaluation of Competencies" section consists of tasks to be carried out based on realistic situations related to the development of energy resources and electricity consumption, while taking into account their environmental impact.

Additional Materials

Have all of the following materials handy.

- A calculator, a lead pencil to write your answers and notes in your guide, a coloured pen to correct your answers, a highlighter to underline key ideas, an eraser, etc.

- The experimental activity booklet containing the materials and products you will need to carry out the experimental activities. You will have to complete this kit by adding certain items to it.

Additional Information Regarding Distance Education

Here are some tips on how to organize your time. This course involves approximately 50 hours of work.

- Draw up a study schedule, taking into account your availability and needs, as well as your family, work and other obligations.
- Try to devote a few hours a week to your studies, preferably setting aside two hours at a time.
- Stick to your schedule as much as possible. This will help you complete the course successfully.

Your tutor will help you throughout this course: he or she will be available to answer any questions you may have, and will correct your scored activities. If his or her availability and contact information were not provided with this learning guide, ask for them at the education centre where you registered for this course. Do not hesitate to consult your tutor if you are having difficulty with the theory or the exercises, or if you simply need encouragment to continue your studies. Make a note of any questions in writing and contact your tutor during his or her available time by telephone and, if necessary, in writing.

Your tutor will guide you throughout the learning process and provide you with advice, constructive criticism and feedback that will help you succeed in your studies.

Overview of a Learning Sequence

The guide includes 7 learning sequences (LS). This is the number of the LS.

The topic of the LS

A presentation of important information regarding the topic of the LS

The list of activities with the specific goal(s) of each one as well as the task related to the experimental activity, the research activity and the expertise-based activity.

4 Electrical Circuits

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In Learning Sequence 3, "Electrokinetics," you saw how an electrical charge travels through a conductor. You also learned how Ohm's law establishes a relationship among the different variables of a circuit: $V = RI$. In this sequence, which comprises five learning activities, you will become familiar with different types of electrical circuits. You will analyze circuits composed of components connected in series and in parallel.

4.1 Series Circuits

Goal ➻ To determine the characteristics of a circuit composed of components connected in series

4.2 Analysis of a Series Circuit

Goals ➻ To analyze a series circuit
➻ To verify the relationships between the variables V, R and I in a series circuit

Your task ➻ You will use a multimeter to measure the variables V, R and I of a circuit composed of components connected in series. Using these measurements, you will infer the characteristics of a series circuit.

4.3 Parallel Circuits

Goal ➻ To determine the characteristics of a circuit composed of components connected in parallel

4.4 Analysis of a Parallel Circuit

Goals ➻ To analyze a parallel circuit
➻ To verify the relationships between the variables V, R and I in a parallel circuit

Your task ➻ You will use a multimeter to measure the variables V, R and I of a circuit composed of components connected in parallel. Using these measurements, you will infer the characteristics of a parallel circuit.

4.5 My Game Console

Goals ➻ To design a game console
➻ To make the game console

Your task ➻ You will design your game console and the electrical circuits in it, assemble these circuits and make sure they are operational.

The exploration activity tests certain concepts that are useful for carrying out the LS.

The answers to the numbered questions are found in the answer key at the end of the guide.

Exploration Activity

The following questions will enable you to test your knowledge of concepts that will be useful in this learning sequence.

4.1 What is the potential difference across the terminals of an AA cell? ____________________

4.2 What is the difference between direct current and alternating current?

____

____

The type of activity is identified by the darkened section in the circle.

The goal(s) to be attained in the activity

Terms and expressions with dotted underlining are defined in the glossary at the end of the guide.

The task to be carried out in the activity is described.

Activity 4.4 Analysis of a Parallel Circuit

Goals

- To analyze a parallel circuit
- To verify the relationships among the variables *V*, *R* and *I* in a parallel circuit

In Activity 4.3 you analyzed a circuit composed of components connected in parallel. Now, you will have an opportunity to verify the results of this analysis experimentally by using a multimeter to measure the three basic variables of an electrical circuit: voltage, current intensity and resistance.

Your task

You will use a multimeter to measure the variables *V*, *R* and *I* of circuit components connected in parallel. Using these measurements, you will deduce the characteristics of a parallel circuit.

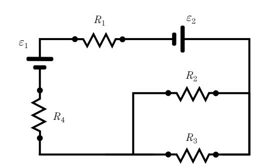
Do the experiment

Refer to the experimental activity booklet that comes with this guide.

Integration exercises are included after the last activity in the LS, and deal with the subject matter covered in the LS.

Integration Exercises

4.39 Apply Kirchhoff's two laws to the following circuit.



a) Current law: ____________________

b) Voltage law: ____________________

4.40 a) Explain why the more light bulbs you connect in series, the less brightly they shine.

b)

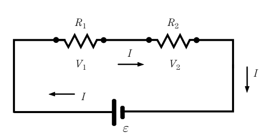
The LS concludes with a summary and review of new knowledge acquired.

Summary of Knowledge Acquired

The components of an electrical circuit can be connected **in series** or **in parallel**.

Series circuits

In a circuit composed of components connected in series, the sum of the current intensities is the same at all points in the circuit since it is the same current that powers all of the components.



A series circuit

The sum of the potential losses across the components is equal to the potential gain across the terminals of the source.

The circuit's equivalent resistance is equal to the sum of the equivalent resistances.

I	The same at all points
V	$\varepsilon = V_1 + V_2$
R	$R_{eq} = R_1 + R_2$

Note: In this course, we do not take the power source's internal resistance into account.

Features of a Learning Sequence

The gray boxes contain concepts and information that are important to remember.

By combining these two proportional relationships, we get: $I \propto \frac{V}{R}$. By using the appropriate units, this proportional relationhsip becomes the equation:

$I = \frac{V}{R}$	where I is the current intensity in amperes (A), V is the voltage in volts (V) and R is the resistance in ohms (Ω).

The numbered figures provide important information; pay close attention to them.

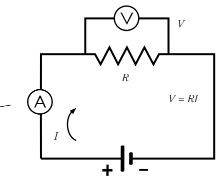


Figure 3.19 A simple circuit that includes an element with ohmic resistance

This equation, better known as $V = RI$, applies only to metal conductors with a constant resistance, that is, one that does not vary with the voltage. Such a resistance is said to be **ohmic**.

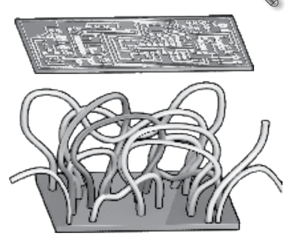
In a circuit, it is symbolized by ⩘⩘⩘.

These sections provide additional information, which is not, strictly speaking, part of the course material. None of the questions on the final examination will deal with the information found in them.

Did you know

Printed circuits

Increasingly complex and miniaturized circuits have made it more difficult and cumbersome to use conducting wires to connect components. This situation was remedied in electronics by replacing wires with thin metal pathways printed directly on plastic plates designed to support the circuits. The connections between components are therefore much less cumbersome and technicians can find their way much more easily when repairs are needed. Such compact assemblies are known as "printed circuits." You can see them by opening up a telephone, a television set or a computer. Printed circuits are made up of resistors, chips and various components connected by means of metal pathways.



The advantage of the printed circuit: A printed circuit board is far more practical than a complex jumble of wires. A picture of a printed circuit was presented in the previous learning sequence.

The exclamation mark beside a paragraph indicates important content.

! Hydro-Québec exports large amounts of electrical energy to New England, in the northeastern United States. In order to synchronize the Québec and American power grids, a 450-kV direct-current line connects the James Bay Radisson substation with the converter station at Sandy Pond near Boston, Massachusetts.

Boxes with a light bulb contain tips to make your work easier.

Tip

Below are some good Internet sources you can consult for this assignment.

- Hydro-Québec: www.hydroquebec.com
- Ministère des Ressources naturelles et de la Faune du Québec: www.mrnf.gouv.qc.ca
- Environment Canada: www.ec.gc.ca

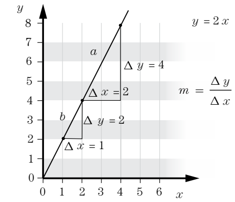
Boxes with a pushpin contain reminders of concepts covered in previous courses.

Reminder

The slope of a line

The function $y = f(x)$ is represented graphically by a straight line if, for any change in the value of x (Δx), there is an equal change in the value of y (Δy). The slope (m) of this line, or its degree of inclination, is described by the ratio $\Delta y/\Delta x$.

For example, the function $y = 2x$ is represented by the graph opposite.



$$m = \frac{\Delta y}{\Delta x} = \frac{2}{1} = \frac{4}{2} = 2$$

This section indicates that you must complete a scored activity and submit it for correction.

You must now do **Scored Activity 1.**

When you finish, hand it in to your instructor, or send it to your tutor in keeping with the arrangements made when you enrolled.

Note: If you do not have the scored activities, you can download them from: **http://cours1.sofad.qc.ca/ressources,** under "Diversified Basic Education."

1 My Energy Needs and Energy Sources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Regardless of what it is we do, we need energy, if only to maintain an acceptable quality of life. We use energy to feed ourselves, to keep warm in the winter, to power our lights, to communicate and to get from place to place. Meeting all of these needs requires a minimum amount of energy. If we add to this the energy that goes into making our recreational activities possible, then our energy needs can be considerable. This learning sequence consists of three activities that will help you take stock of your energy needs and energy sources.

1.1 My Energy Needs

Goals
- To determine the energy needs of a person living in Québec
- To make a list of the appliances and devices used to meet these needs

1.2 My Energy Sources

Goal
- To identify the energy sources used in various activity sectors in Québec

1.3 My Energy Habits

Goal
- To inform a pen pal about the various sources of the energy you use

Your task
- You will:
  a) make a list of the appliances, devices and services that require an energy source and that you use on a regular basis; b) identify the advantages, drawbacks and environmental impact of these appliances, devices and services; and c) write a text.

Exploration Activity

The following questions will enable you to test your knowledge of concepts that will be useful in this learning sequence.

1.1 What is the most commonly used form of energy in Québec homes?

1.2 What sector of activity in Québec consumes the most petroleum products?

1.3 Describe how energy is transformed in an electric light bulb.

1.4 What type of power plant produces most of the electricity consumed in Québec?

1.5 Name one clean energy source that is undergoing rapid growth in Québec.

Activity 1.1 My Energy Needs

Goals

- To determine the energy needs of a person living in Québec
- To make a list of the appliances and devices used to meet these needs

In order to survive, many animals have developed different ways of gathering food, hunting prey and fleeing from predators depending on their position in the food chain. They dig burrows or build shelters to protect themselves from bad weather and predators.

Humans have created an artificial environment for themselves and must maintain it to ensure their survival. The needs of a person living in Québec today can be grouped into five categories: food, heating, lighting, communication and transportation. These needs require a lot of energy, particularly electrical energy.

Below is a table that shows the amount of electricity typically consumed in Québec homes. We will be referring to this information throughout this activity.

Table 1.1 – Breakdown of typical residential electricity consumption in Québec in 2010

Use	Percentage (%)
Heating	54
Water heater	20
Electrical appliances	18
Lighting	5
Other	3

Source: Hydro-Québec

Food

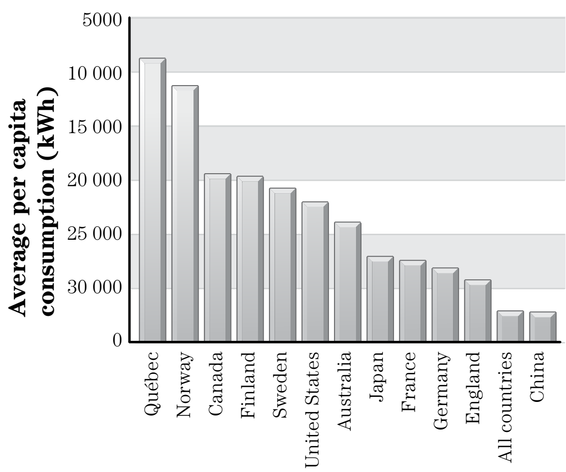
In the past, most people lived on small family farms and were practically self-sufficient where food was concerned. Today, city dwellers must rely on specialists (crop producers, livestock farmers, etc.) to meet their need for food. However, even livestock farmers and crop producers, who often specialize in a single type of livestock or crop, depend on others to supplement their food sources.

Often, food must travel considerable distances to reach us. This is especially true of imported products. Just think of the fruit that comes from the United States, Mexico and South America, particularly in winter. This type of transportation in refrigerated trucks requires an enormous amount of energy.

Heating

In our corner of the world, where the thermometer sometimes dips to –30°C and lower, keeping warm is a matter of survival. It's not surprising, then, that heating is the largest energy expense in Québec, accounting for roughly 54% of households' demand for electricity. This is a lot of energy, especially since water heating is the second largest energy user in today's households and accounts for about 20% of the total energy bill. Improved home insulation and more efficient heating appliances have played a significant role in stabilizing the growing demand for energy despite the increase in the number of households.

Graph 1.1 – Average per capita consumption of electricity, Québec and selected countries, 2009



Source: International Energy Agency, 2011

The high electricity demand for home heating partly explains why average per capita electricity consumption in Québec is so high. Another reason for this high consumption is the fact that a large portion of Québec's industry is based on very energy intensive sectors such as paper manufacturing and aluminum smelting. The graph opposite shows the average per capita electricity consumption in Québec compared with that of selected countries. Note that the so-called "northern" countries consume more energy.

Lighting

Up until 1879, candles, torches and oil lamps were the only sources of artificial light. Today, flicking a switch is so natural that we tend to take electricity for granted, and yet the resulting light meets a need that is all the more essential in a region where it gets dark by four o'clock in the afternoon in winter. Indeed, without artificial lighting to extend the day, we would not be able to carry on industrial, commercial, sports, institutional and other activities after dusk. Surprisingly, even though electric lighting is widely used in residential buildings, the energy consumption it represents is low, accounting for only 5% of a household's electric bill.

1.6 Name three fields or activities in which artificial lighting is essential.

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Communication

We live in an era of instantaneous communications and social media. Imagine life without computers or smart phones that enable you to stay connected to others. Here too, even though none of these electronic devices consumes huge amounts of electricity inidividually, they have become so common that, taken together, they account for a sizable amount of energy consumption.

1.7 Name two other electronic devices that allow you to communicate with others.

Transportation

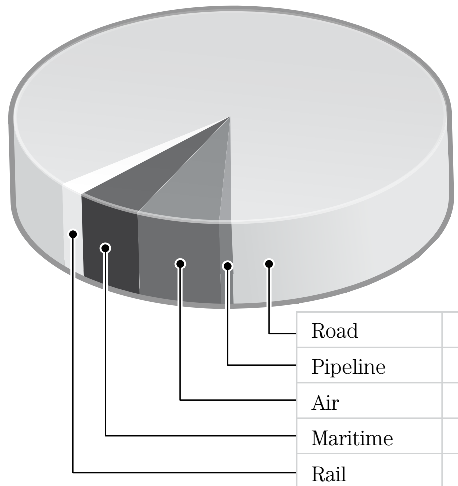
If you travel on foot or by bike, you are using your own physical energy; however, all other means of transportation require energy for which you must pay, in one way or another. For public transit (buses and metro), you pay the cost of the ticket; for a taxi, you pay the fare; and lastly, if you drive your own car, you pay for the gas, diesel fuel or electricity, in addition to paying for the actual vehicle and maintenance.

1.8 Name three other means of transportation you can use that involve expenses.

Did you know?

In 2009, road transportation alone accounted for close to 86% of the total energy used by Québec's transportation sector. The diagram opposite shows energy consumption by mode of transport.

Breakdown of energy consumption by mode of transport in 2009



Road	85.8%
Pipeline	0.9%
Air	6.2%
Maritime	5.0%
Rail	2.1%

Sources: MRNF Québec and Statistics Canada

My appliances

We can define technology as all of the methods used to convert one form of energy into another that can be used for a given purpose.

Energy is the capacity to do work and it exists in a number of forms. Listed below are a few forms of energy that will be discussed in this learning sequence.

- Electrical energy is the energy in an electrical current.
- Kinetic energy is the energy in a moving object.
- Thermal energy, or heat, is the energy produced by vibrating molecules.
- Chemical energy is energy stored in the bonds of atoms and molecules; batteries and different types of fuel are examples of stored chemical energy.
- Radiant energy is energy that is carried by radiation, and includes visible light.

The concept of energy will be further developed in Activity 6.1, "Work, Energy and Energy Efficiency."

A number of appliances and systems have been developed to meet each of the needs presented earlier. A few of them are discussed below, and their descriptions focus on energy transformations. In each case, an energy chain summarizes these transformations.

Food in the refrigerator

The long distances food must travel in order to reach us and the need to then preserve it for several days in our homes have made refrigerators practically indispensable.

A refrigerator's cooling capacity is based on the principle that a liquid absorbs heat when it vapourizes.

For example, if we pour a little rubbing alcohol on our skin, it will feel cold as it evaporates and absorbs the heat from the surface of our skin.

A special coolant called a refrigerant functions in a refrigerator the way alcohol works on our skin, except that in a refrigerator, the coolant is trapped inside a closed circuit. The compressor constricts the refrigerant vapour, raising its pressure and pushing it into the condenser coils. When the hot gas meets the cooler air temperature of the kitchen, it becomes a liquid. Now in liquid form at high pressure, the refrigerant cools down as it flows into the coils inside the refrigerator. The refrigerant absorbs the heat inside the unit, cooling down the air. Last, the refrigerant evaporates to a gas and flows back to the compressor, where the cycle starts all over again.

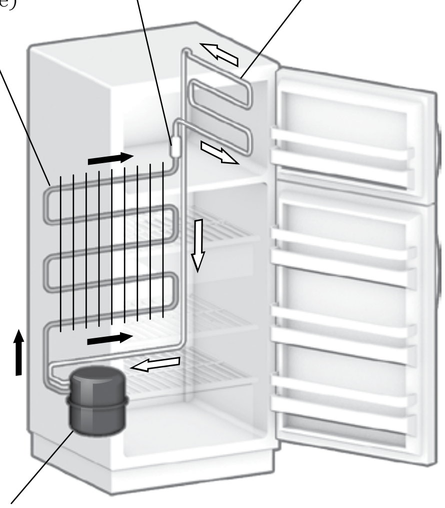


Figure 1.1 Components of a refrigerator

The compressor's motor transforms electrical energy into kinetic energy (the energy of motion). The energy chain is as follows:

Electrical energy → Kinetic energy

The light bulb that lights up the inside of the refrigerator converts electrical energy into light and heat. The energy chain is as follows:

Electrical energy → Light energy + Thermal energy

1.9 Write the energy chain for a microwave oven.

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Keeping warm with electric heating

An electric baseboard heater is powered by a 120-V or 240-V electrical source and is connected to a thermostat. The electrical current heats a conductor that in turn heats the metal fins or elements. In this way, electrical energy is converted into thermal energy. This concept will be discussed in more detail in Activity 6.2, "Power and Energy Consumption."

The energy chain is as follows:

Electrical energy → Thermal energy

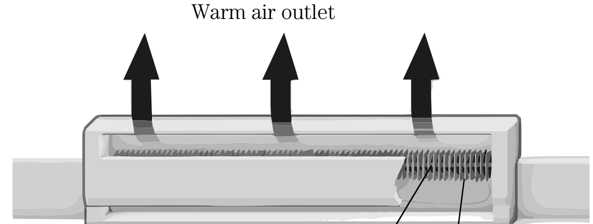


Figure 1.2 Components of an electric baseboard heater

1.10 Write the energy chain for a heating system that runs on fuel oil or natural gas.

Lighting and the electric light bulb

The incandescent light bulb soon became indispensable after it was invented by Thomas Alva Edison in 1879. Other types of light bulbs have been developed since: fluorescent tubes, halogen headlights, compact fluorescent bulbs, light-emitting diode (LED) lamps, etc.

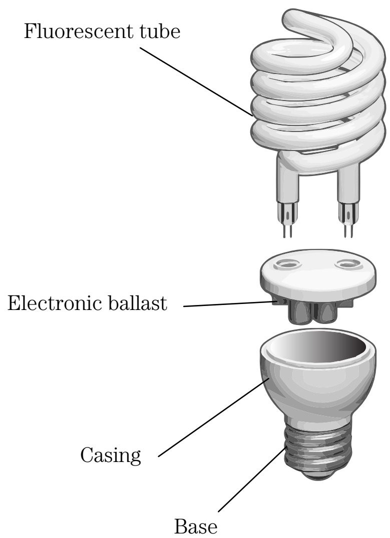


Figure 1.3 Components of a compact fluorescent bulb

Regardless of the type of bulb, it serves to convert electrical energy into useful light energy and heat. The energy chain for a light bulb is as follows:

Electrical energy → Light energy + Thermal energy

Let us now look at how a compact fluorescent bulb (CFL) works. A compact fluorescent bulb is a fluorescent light bulb that has been compressed into the size of a standard-issue incandescent light bulb. The fluorescent tube contains mercury vapour. When an electrical current is driven through the tube, the mercury atoms emit invisible ultraviolet (UV) light that excites a fluorescent coating on the inside of the tube. In turn, this coating absorbs the UV light and emits visible light.

Only about 40% of the energy supplied to an incandescent light bulb is converted into light; the remainder is dissipated as heat. Other types of bulbs convert most of the electrical energy supplied to them into light and therefore generate a lot less heat. The most efficient ones are LED bulbs.

1.11 Write the energy chain for a propane lamp.

Communicating via smart phones

A smartphone is a multifunction device that can be used as a computer, a camera and a telephone. Its operation depends on several energy transformations. Here is how it works when you receive or make a call.

In receive mode:

The chemical energy in the battery is converted into electrical energy as needed. The electrical energy is then converted into light energy (the screen) and sound energy (as needed), which is a form of kinetic energy associated with the movement of molecules in the air. The energy chain is as follows:

Chemical energy → Electrical energy → Light energy (radiant energy) + Sound energy

In transmission mode:

Let's take the example of videoconferencing, which involves all of the functions of the telephone. Sound and light enter the device, where they are converted into an electrical current. The energy chain is as follows:

Sound energy + Light energy → Electrical energy

In receive and transmission mode:

When the device is running, the battery powers the electronic circuit, which in turn activates the screen. Here is the energy chain:

Chemical energy → Electrical energy → Light energy + Sound energy

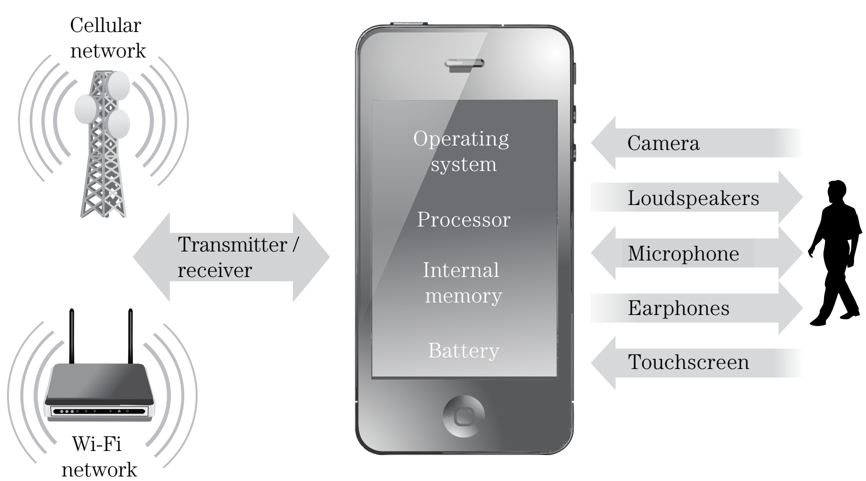


Figure 1.4 Components of a smartphone

1.12 Write the energy chain for a computer tablet in receive mode.

Getting around in electric cars

Thanks to increasingly efficient and lightweight batteries, the automobile industry is able to offer consumers electric vehicles (EV) that are increasingly better performing and less polluting.

A network of charging stations is being set up where EV drivers will be able to stock up on electrical energy just as they would fill up on gasoline for a traditional car. For a car that runs entirely on electricity, the chemical energy stored in the battery is converted into electrical energy as needed. Electrical energy is converted into kinetic energy (engine's rotation), and the engine's kinetic energy is then transmitted to the wheels by the transmission system. Part of the electrical energy is converted into:

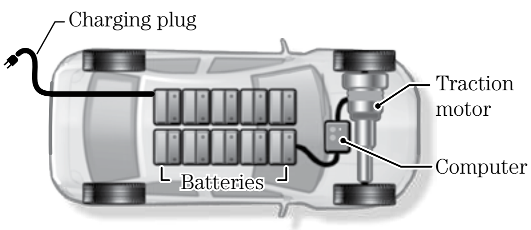


Figure 1.5 Components of an electric car

- sound energy, by the sound system;
- light energy, by the lighting system;
- thermal energy, by the car heater and the braking system.

Here is the corresponding energy chain:

Chemical energy → Electrical energy
→ Kinetic energy + Sound energy + Light energy + Thermal energy

1.13 Write the energy chain for a traditional gasoline-powered car.

Exercises for Activity 1.1

1.14 List the five energy needs mentioned in this activity in decreasing order of priority (from the most important to the least important), according to your own personal assessment.

1.15 Which of the five needs discussed in this activity requires the most energy?

1.16 What technology allows us to transport perishable food items from as far away as Chile?

1.17 Give two reasons why average per capita electricity consumption in Québec is so high.

1.18 Which of the five needs discussed in this activity requires the least amount of energy?

1.19 What mode of transportation consumes the most energy in Québec?

1.20 What are the energy transformations that occur in an incandescent light bulb?

1.21 Why does a compact fluorescent bulb consume less energy than an incandescent light bulb?

1.22 What energy transformations occur in a cell phone that is in receive mode?

1.23 Write the energy chain for an electric metro train.

Activity 1.2 My Energy Sources

Goal

- To identify the energy sources used in various activity sectors in Québec

Now that you have identified your energy needs, let's look at the energy consumption of Quebecers as a whole and where this energy comes from.

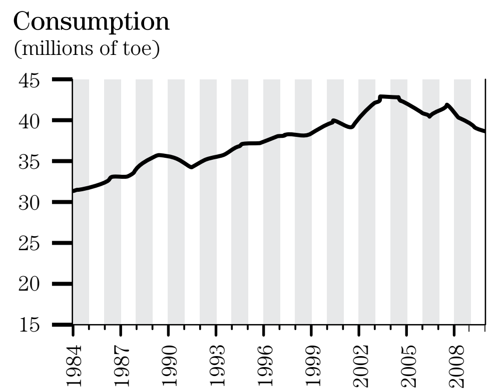
Energy consumption in Québec

In 2009, Québec's total energy consumption was 39 million tonnes of oil equivalent (toe). The toe is commonly used in statistics on energy consumption and production. A tonne of oil equivalent is equal to 4.3×10^{10} joules. The joule (J), which is the unit for energy, will be discussed in detail in Learning Sequence 6, "Sources and Uses of Electrical Energy." For example, a person's food energy needs over a one-year period are of the order of 0.1 toe.

The graph opposite shows the change in total energy consumption in Québec from 1984 to 2009.

This energy comes from the following sources.

Graph 1.2 – Total energy consumption in Québec from 1984 to 2009



Sources: Ministère des Ressources naturelles et de la Faune du Québec and Statistics Canada

Table 1.2 – Sources of the energy consumed in Québec in 2009

Source of energy	Consumption	Percentage (%)
Electricity	182.6 terawatthours[1]	40
Petroleum products	17.4 billion litres	39
Natural gas	5.3 billion cubic metres	13
Biomass[2]	2.9 million toe	7
Coal	550 kilotonnes	1

Sources: Ministère des Ressources naturelles et de la Faune du Québec and Statistics Canada

1. The kilowatthour (kWh) is a unit of electricial energy. One terawatthour (TWh) is equal to 10^9 kWh.
2. Biomass refers mainly to the use of wood as fuel. The residential sector consumes 35% of the biomass-derived energy and the industrial sector (pulp and paper, wood processing and sawmills), 65%.

Did you know?

Running on ethanol

Gas engines can use 10% ethanol (ethyl alcohol) blended fuels with no modifications. Alcohol is made from fruit, grains (including corn) or grasses through a process of fermentation followed by distillation.

© Vaclav Volrab / Shutterstock.com

A corn field

In an effort to reduce their dependence on oil, several countries are using corn to produce ethanol. In 2010, for example, Brazil earmarked 35% of its corn crop for ethanol production, with the remainder being fed to livestock. This percentage was 40% for the United States. By comparison, Québec devoted only 10% of its corn crop to ethanol, which is produced in a single processing plant located in Varennes, on Montréal's south shore.

The use of cereal grains for fuel production poses an ethical problem. A number of people maintain that cereal grains should be used to feed people, not cars. This is even more true given that intensive corn production, a monoculture, requires large amounts of fertilizers and pesticides and results in soil erosion.

Québec will focus on cellulosic ethanol, which involves producing ethanol from forest waste and pulp and paper residues. This process is more complex and more costly since enzymes are used to extract sugars from wood cellulose prior to fermentation. Pilot projects to produce cellulosic ethanol are already under way and this technology looks promising.

Consumption by activity sector

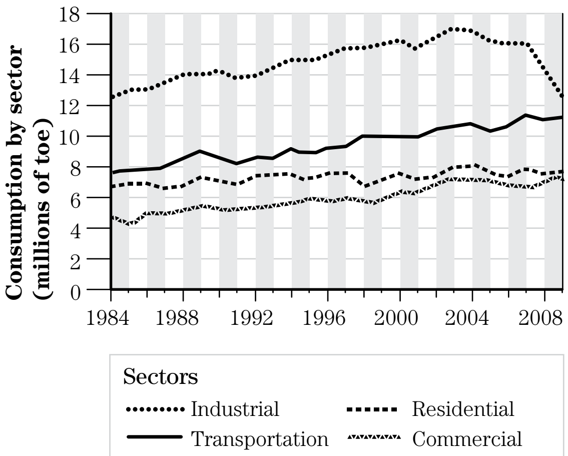
The following table gives the breakdown of Québec's total energy consumption in 2009, i.e., 39 million toe.

Table 1.3 – Breakdown of energy consumed in Québec by activity sector in 2009

Sector	Percentage (%)	Sector	Percentage (%)
Industrial	33	Residential	19
Transportation	29	Commercial	19

Sources: Ministère des Ressources naturelles et de la Faune du Québec and Statistics Canada, 2009

Graph 1.3 – Energy consumption by activity sector from 1984 to 2009



Sources: Ministère des Ressources naturelles et de la Faune du Québec and Statistics Canada

The graph opposite shows the change in these values since 1984.

If we look at the curves in this graph, we see that energy consumption in the industrial sector grew until 2003. From 2003 to 2009, the effects of the recession resulted in a 20% drop in consumption. In the transportation sector, energy consumption grew steadily, with the lion's share being gobbled up by road transportation. The residential and commercial sectors saw moderate increases, which can be explained by improved energy efficiency, particularly with respect to insulation and heating systems, despite the rise in the number of businesses and residential units.

1.24 Propose ways to reduce your energy consumption in the areas of transportation and heating.

a) Transportation: ______________________________

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b) Heating: ______________________________

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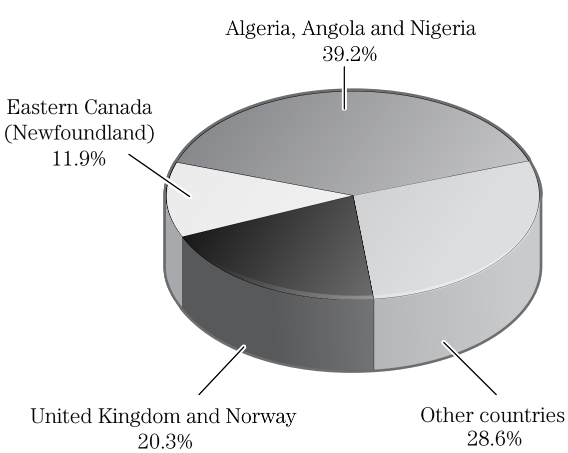
Graph 1.4 – Breakdown of Québec's crude oil supplies by country in 2010



Sources: Ministère des Ressources naturelles et de la Faune du Québec and Statistics Canada

Where energy comes from

Electricity

Electricity is the crown jewel of Québec's energy sources, and most of it is produced by our hydroelectric power plants. We will come back to this topic in Learning Sequence 7, "Hydroelectricity."

Oil

Québec imports all of the oil it consumes, which accounts for 39% of our overall energy consumption. In 2010, oil from Africa (Algeria, Angola and Nigeria) accounted for 39.2% of the total amount of oil imported. The other major supply sources were the North Sea (the United Kingdom and Norway, 20.3%) and Eastern Canada (Newfoundland, 11.9%).

Natural gas

Unlike oil, natural gas is easily transported by underground pipelines since the costs of maritime transportation are very high. Fortunately, in 2012 Canada held 1% of the world reserve of natural gas, which is sufficient to meet the country's demand for the next 80 years. Almost all of the natural gas consumed in Québec comes from Western Canada. The gas is harvested at source, compressed in natural gas pipelines, and transported across Canada at a speed of about 40 km/h, arriving in Québec four days later.

Coal

There are no coal-combustion plants in Québec. Coal is little used here, given the vast hydroelectric resources available in this province. The little coal that is used by Québec's industrial plants is therefore imported for the most part from the western provinces (British Columbia, Alberta and Saskatchewan), which are the main producers in Canada. More than half of the coal supply is used to produce electricity and to meet various industrial needs, notably in the steel and cement industries, and the remainder is exported to foreign markets.

Readily available and relatively inexpensive coal resources mean that coal is the main fuel used by thermal power plants to produce electricity in the various Canadian provinces. This corresponds to some 74% of Alberta's demand for electricity, 63% of Saskatchewan's, 60% of Nova Scotia's and 18% of Ontario's. Coal consumption may eventually decline owing to measures intended to reduce greenhouse gas emissions, notably through the closing or modernization of coal-powered plants.

Nuclear energy

Besides certain medical and military applications, nuclear energy is used mainly in electricity production. As we will see in Learning Sequence 6, fission of the uranium or plutonium nucleus in a nuclear plant releases the heat required to produce vapour. The vapour activates a turbine that drives an generator that produces electricity.

A number of industrialized countries use nuclear energy to meet their electrical energy needs. In Québec, where approximately 97% of the electricity comes from hydroelectric power stations, the only nuclear generating station, Gentilly-2, which was built in the 1970s, has ceased operations.

Biomass

There are three distinct biomass sources: forest residues, agricultural crops and biodegradable waste. In Québec, biomass refers mainly to the use of wood as a fuel since it is considered that the primary purpose of agricultural land is to feed people. The amount of energy produced from biodegradable waste (manure, slaughterhouse waste, emissions from landfill facilities, etc.) was still minimal at the time this guide was being written.

Québec has massive areas of forest land, a resource which has the advantage of being renewable. However, forest biomass is not well-regarded from an enviromental viewpoint. Although improper combustion generates large amounts of atmospheric pollutants, effective technologies now exist that greatly decrease such emissions. Examples of such technologies are pellet stoves and fireplaces and energy-efficient industrial boilers. The forest industry is a major economic force in Québec; however, the demand for Québec timber has declined since the beginning of the 2000s and Québec is facing increasing foreign competition (notably from Russia and China) on lumber markets. Thus, Québec will no doubt consider the use of forest residues as an energy source, as have other countries such as Norway which, while having vast hydroelectric resources like Québec, is diversifying its energy portfolio.

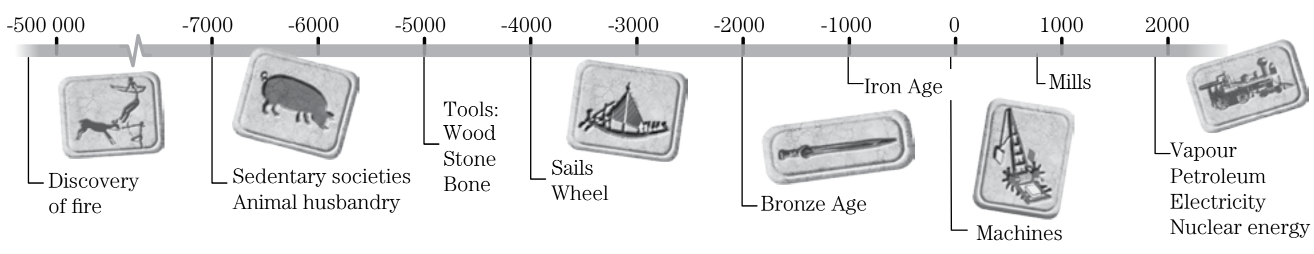
The evolution of energy

The technology that was developed in order to harness the various energy sources that we use today is the fruit of thousands of years of evolution. Half a million years ago, our ancestor *Homo erectus* succeeded in taming fire. That was the first controlled energy source. Our human ancestors were nomadic hunter-gatherers.

Then, in the Near and Middle East more than 9000 years ago, settlements became more sedentary, as people realized that cultivating crops was more effective than foraging for food and that raising livestock was more efficient than hunting animals. Our ancestors' tools were made of wood and stone. Roughly 5000 years later, they learned to use bronze (a copper and tin alloy) to make tools and began to forge iron, a harder and more resistant metal than bronze. In the meantime, the wheel and the sail had been discovered. Antiquity saw the advent of machines (winches, pulleys, etc.). In the Middle Ages, windmills and water wheels were being used throughout Europe. Until the 17th century, humans, draught animals, wind and water were the only sources of motor energy. Then came the Industrial Revolution, which began in Great Britain with the invention of the coal-powered steam engine. Mass produced goods replaced handmade goods and steamships replaced sailing ships.

In the 19th century, the invention of the internal-combustion engine, powered by gasoline or diesel fuel, ushered in an era in which oil was the main source of energy. Likewise, the invention of the electric engine and the electricity generator provided a practical and effective form of energy for the manufacturing and residential sectors.

Today, electricity and oil are the two most common energy sources in Québec.



The evolution of energy use, from prehistory to today

Exercises for Activity 1.2

1.25 What is the most commonly used form of energy in Québec?

1.26 According to the curve in the graph of Québec's total energy consumption from 1984 to 2009 (see Graph 1.2, p. 30), what was this consumption in 2003?

1.27 What is meant by biomass with respect to the energy consumed in Québec?

1.28 What activity sector consumed the most energy in 2009?

1.29 How can we explain the decline in energy consumption in the industrial sector from 2003 to 2009?

1.30 What continent provided most of the oil Québec imported in 2010?

1.31 Which area(s) of Canada provided Québec with the Canadian oil it imported in 2010?

1.32 What were the sources of motor energy that humans could rely on before the Industrial Revolution in the 1800s?

1.33 What invention sparked the Industrial Revolution?

1.34 What invention brought about massive oil consumption?

Activity 1.3 My Energy Consumption

Goal

- To inform a pen pal about the various sources of the energy you use

Your task

- You will:

a) make a list of the appliances, devices and services that require an energy source and that you use on a regular basis;
b) identify the advantages, drawbacks and environmental impact of these appliances, devices and services; and
c) write a text.

The list

Make a list of at least three appliances (e.g., propane barbecue) and three services (e.g., bus transportation) that you use on a regular basis. Specify the energy source involved in each case as well as the energy transformations that occur.

Appliances	Source of energy	Energy chain

Services	Source of energy used	Energy chain

Benefits, drawbacks and environmental impact

Identify the benefits, drawbacks and environmental impact of each appliance and service in your list.

Appliances	Benefits	Drawbacks	Environmental impact

Services	Benefits	Drawbacks	Environmental impact

The text

Last, draft a one-page text that you will send to your pen pal. Emphasize the benefits you derive from the appliances and services on the list as well as their drawbacks, especially their environmental impact. End your text with a conclusion in which you assess your energy consumption and propose ways, both individual and collective, of reducing the economic and environmental impact of your consumption.

Integration Exercises

1.35 Name two needs that can be met by using oil as a source of energy.

1.36 Which need discussed in this learning sequence owes its importance to our geographic location, and why?

1.37 With regard to energy sources, what transition is likely to reduce the pollution created by the transportation sector?

1.38 What form of energy is essential to our need to communicate?

1.39 Give two reasons why it is preferable to use electricity rather than oil.

Summary of Knowledge Acquired

My energy needs

Humans need to eat, keep warm, have light, communicate and travel. These needs require a great deal of energy:

- most foods that are transported over long distances must be refrigerated;
- in our cold climate, heating involves the use of large amounts of energy;
- artificial lighting is indispensable for activities that are carried out well after dusk.

Communications play an important role in our lives. While the electronic devices we use to communicate with one another use little electricity, their sheer numbers mean that they account for a sizable amount of our energy consumption.

Means of transportation, both individual and collective, require a great deal of energy.

My appliances

To meet each of these needs, various appliances, devices and systems have been developed that use different forms of energy. Here are some examples:

- In order to eat, we use electrical energy, or the energy in an electrical current, to refrigerate our food or cook it in the oven.
- To travel, we use kinetic energy, or the energy of a body in motion, to power our vehicles.
- To heat our homes, we use thermal energy, or the energy associated with the vibration of molecules, to heat the conductors in electric baseboards.
- To communicate with one another, we use chemical energy, which is stored in the batteries we use to power our communication devices.
- For lighting, we use radiant energy, which is carried by radiation, to produce light energy.

My energy sources

In 2009, Québec's total energy consumption was 39 million tonnes of oil equivalent (toe) and was divided as follows: 40% in the form of electricity; 39% in the form of petroleum products; 13% in the form of natural gas; 7% in the form of biomass, essentially wood; and 1% in the form of coal.

Of this energy, 33% was used by the industrial sector, 29% by the transportation sector, 19% by the residential sector and 19% by the commercial sector.

Where energy comes from

The main source of the energy used in Québec is electricity, which is produced by our hydroelectric resources.

Most of our oil is imported from Africa, the North Sea and Eastern Canada (Newfoundland).

Most of our natural gas comes from Western Canada; it is transported to Québec through underground pipelines.

Québec has no coal-fired power plants; it therefore uses very little coal. The little coal that is used serves to produce electricity for certain industrial plants (steel and cement). Coal comes mainly from Western Canada.

Nuclear energy is used by several industrialized countries to produce electricity. In Québec, the nuclear reactor used to produce electricity ceased operations years ago.

Biomass comes from Québec's forests, a renewable resource that is in abundant supply in Québec. The forest industry is a major economic force in Québec, and the use of biomass as an energy source may grow in the future.

The evolution of energy

The domestication of fire dates back 500 000 years. Ever since human settlements became sedentary, more than 9000 years ago, different technologies enabled humans to exploit various sources of energy.

Humans were eventually able to add the energy provided by wind and water to that provided by draught animals. The invention of the steam engine sparked the Industrial Revolution. The invention of the internal combustion engine ushered in the era fossil fuels. The invention of the electric engine and the electricity generator gave rise to the development of our main source of energy: electricity.