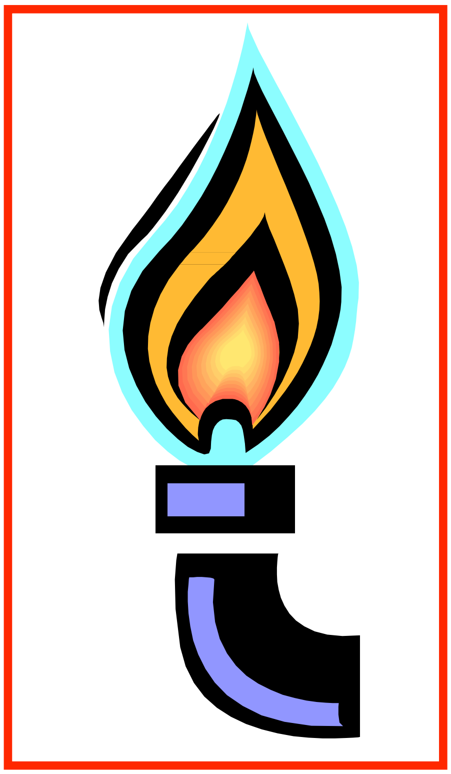
centre de développement pédagogique
pour la formation générale en science et technologie



BIOGAS

STUDENT BOOKLET

WORKING DOCUMENT

Table of contents

Methane released into the atmosphere!

NOTE: This LES was designed within the framework of training sessions. It will require adaptation before being used with students.

Trace amounts of gases in the atmosphere play the same role as the panes of glass in a greenhouse. These trace amounts of gases retain a great deal of the sun's heat close to the surface of the Earth during the night. These gases, called greenhouse gases (GHG), help to maintain the climates we know on Earth. Without these GHG, our planet would be a veritable icebox! Too much heat, however, can also be detrimental. Indeed, an increase in these gases also means an increase of the global temperature on our planet. The greenhouse effect is essential to life, but an increase in the greenhouse effect necessarily has an impact on the evolution of life on our planet. Research tends to show that much colder or much hotter episodes have occurred. Every time, the planet's biodiversity has known great upheaval.

There are four principal greenhouse gases, CO_2 being the most often cited as the one most responsible for the greenhouse effect. Water vapour (H_20), methane (CH_4) and nitrous oxide (N_2O) are the three other most important gases, while chlorofluorocarbons (CFCs) and hydrofluorocarbons (HCFCs), used in refrigeration, also contribute to the greenhouse effect.

Suggestion of a video available on YouTube:
http://ca.youtube.com/watch?v=T8TZ_1w3uLY

Let's look at methane…

Methane (natural gas) is produced when organic materials decompose (rot) in an environment without oxygen (anaerobic decomposition). This happens in nature. This phenomenon is at the origin of deposits of fossil fuels (hydrocarbons – oil and natural gas) that are extracted by man to produce energy.

Organic matter from dead vegetation and animals is deposited on ocean beds and is found in their sediments. In the superior layers of the sediment, in the absence of oxygen and light, with the action of anaerobic bacteria (found naturally in organic matter), this matter becomes transformed into methane. A part of the methane combines with water molecules to form what is called methane hydrate[1]. Other than the continental selves in the ocean beds, these methane hydrates are found in the permafrost of very cold regions.

Suggestion of a video available on YouTube:
http://ca.youtube.com/watch?v=B36EoEuKjVg

Your challenge:

As the enlightened citizens that you are, and as researchers in training, you will have to look at the energy output of a biogas[2] produced by a bio-digester, experimentally. Using your knowledge about this subject you must estimate the environmental impacts of such a process.

To help you in your mission, we suggest that you become familiar with certain concepts relative to environmental education as well as to scientific concepts and techniques related mainly to chemistry.

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[1] Methane hydrate is formed from water molecules forming dodecahedral cages that trap gas molecules like methane and hydrogen sulphide. These cages can store considerable quantities of gas (for example 164 cm^3 of methane in 1 cm^3 of methane hydrate). – Source : Wikipedia, January 19th 2009.

[2] Combustible gas produced by the decomposition of organic matter. – Source : Antidote Prisme

Warm-up period (without biogas!)

Construction of a network of concepts associated to the proposed challenge…

Having viewed the two short video sequences, read the introduction and using your current knowledge, elaborate a network of knowledge using the terms suggested below. You may add any concepts you feel may be useful to complete it.

Organic matter	Energy	Atmosphere
Permafrost	Fossil fuels	Residual matter
Anaerobic decomposition	Greenhouse gases	Combustion
Climate change	Methane	Exothermic reaction

Biogas

Personal notes:

Greenhouse effect

Modeling the greenhouse effect: diagram the suggested assembly; note your suggested observations and explanations.

Diagram of assembly

Suggested observations and explanations:

Do we have individual responsibility and power of action over the greenhouse effect?

You have certainly heard the term «ecological footprint» in the last few months. This relatively recent concept in the history of environmental education is attributable to two researchers from the University of British Columbia in Vancouver who created a tool to estimate the environmental impact of societies. In 1996 they published a paper entitled «Our Ecological Footprint: Reducing Human Impact on the Earth» by Mathis Wackernagel and William E. Rees.

This tool, judged useful by many proponents in research and environmental education, has been used throughout the world. The concept is drawn upon more and more to sensitise the planet's population to the effects of our individual habits of consumption and lifestyle. It attempts to estimate and quantify these habits using a mathematical tool. It is then possible to use the data gathered for comparison and follow-up purposes to estimate the effects (good and bad) of our actions on conservation, balance and maintenance of the resources of the planet. These preoccupations are intimately linked to the concept of sustainable development.[3]

Mr. Wackernagel and Rees's calculation tool allows us to quantify, in terms of area (hectares) of terrestrial and aquatic resources, what is necessary to an individual or community to produce the food, goods, energy and to absorb the residual matter of its consumption.

> «The ecological footprint is the area of productive land and aquatic ecosystems necessary to produce the resources used and to assimilate the waste produced by a defined population at a specified level of materialism, wherever that land is on the planet. » (Rees, 1996)

Several calculation tools are available on the Internet. We suggest one in Annex 1. It is available on the "*Green Teacher*" website.

[3] «Development that responds to current needs without compromising the capacity of future generations to respond to theirs. Sustainable development is based on a long term vision that takes into account the indivisible character of environmental, social and economic dimensions of development activities. » - Definition of the Ministry of Sustainable Development from Environment and Parks Quebec.

Some facts that warrant your attention…

Relative importance and life span of the principal greenhouse gases

Greenhouse gases (GHG)	Approximate duration in the atmosphere	Potential for warming over a 100 year period, as compared to CO_2	Percentage of responsibility attributed for climate change in the last century	Origin
Carbon dioxyde (CO_2)	50 to 200 years depending on the estimate	1	54,9 %	Combustion of oil and gas, cement manufacturing, deforestation and naturally produced by photosynthesis, volcanic eruptions and forest fires.
Methane (CH_4)	12 years	20 to 23 depending on the estimate	18 %	Oil and gas production, coal mining, rice fields, garbage dumps, and produced naturally by organic matter decomposition and cattle digestion.
Nitrous oxide (N_2O)	120 years	296	5,6 %	Combustion of hydrocarbons, coal and of wood; fertiliser, coal mining and naturally produced.
Other GHG	Various	Various	20,3 %	Cooling fluids and industrial pollution.

Source: ClimateChangeNorth.ca – Information table on greenhouse gases.

Biogas

Biogas is a gaseous mixture produced in the course of a natural biological process called anaerobic digestion. In the absence of oxygen, methane bacteria decompose organic matter and during this operation, produce a gaseous mixture made up principally of methane and carbon dioxide in respective proportions of about 60% and 40%. Biogas produced during this process is released into the atmosphere.

The discovery of methanogenesis is attributed to Alessandro Volta[4] in 1776. It seems that Mr. Volta, while on a walk, had noticed gaseous emanations from a swamp. Having explored the phenomenon, he discovered that the gas was flammable. At the time this gas was called "swamp gas". Two years later, in 1778, he successfully isolated methane.

While this process is natural – swamp, peat bogs, tropical forests, tundra and animal digestion (mostly from ruminants) – large scale cattle farming as well as the storage of residual matter in garbage dumps contribute significantly to the quantity of atmospheric methane. The potential for methane warming is found in the table on the preceding page.

Since this gas is flammable, the energy produced by its combustion has applications in various fields. Humans need energy for heating, cooking their food and transforming resources. Scientific knowledge and technological innovation have allowed for the production and recovery of this gas by building "digesters"[5].

In India and China, hundreds of thousands of « rudimentary home digesters » allow families to cook on biogas burners. During the Second World War, German army vehicles equipped with gas powered motors worked on biogas recovered from farm manure.

During the last fifty years, remarkable technological and scientific progress in the development of anaerobic digestion systems has allowed the increase in the productivity of methane (CH_4) from organic waste.

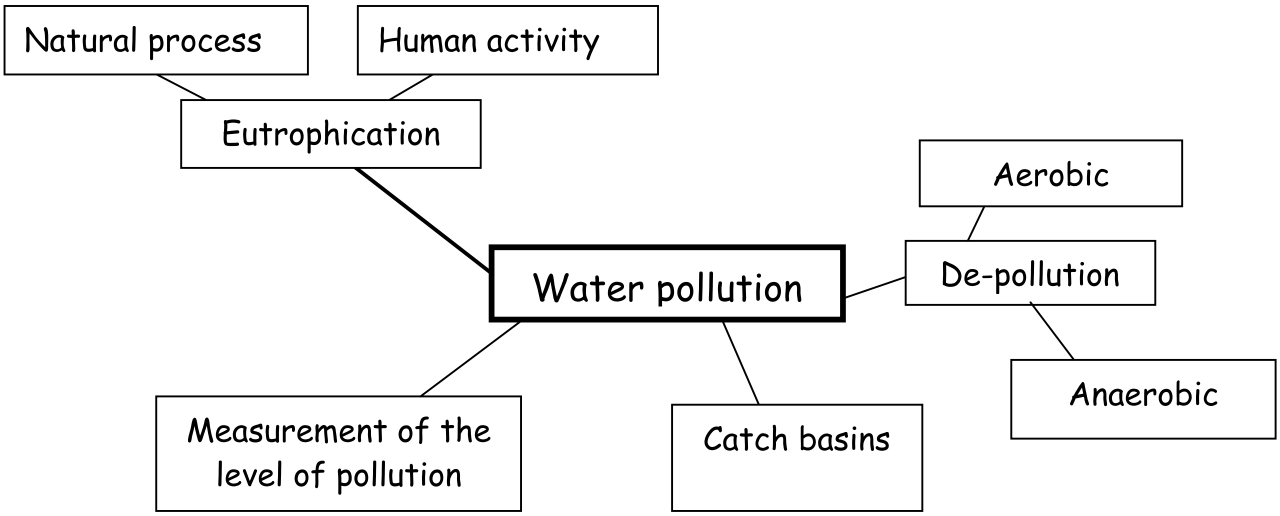
These days there are an ever increasing number of installations for the production of methane from residual organic matter – mud from water treatment plants, cattle manure, residential garbage dumps. In Europe, entire villages are supplied with electricity from centralised biogas production installations.

[4] Alessandro Volta (1745 - 1827) was an Italian physicist. He is known for his work in electricity and for the invention of the first battery called the voltaic battery. – Source : Wikipedia, January 21st 2009.

[5] Name given to the mechanism that allows for the production and recovery of biogas in an enclosed area. It is a matter of digesting organic matter of vegetal or animal origin.

Water pollution

Concepts exploration card



Polluted water is water in which there are, essentially, dissolved or suspended solids. Industry uses a considerable amount of water for the transformation of resources, fabrication of consumer goods and food products. We cannot ignore the water needed for agriculture.

Surface water finds itself in the water table or in neighbouring streams after the soil is washed over. Obviously, this water may contain various solids and micro organisms depending upon the upstream usage of the water.

1. What is eutrophication? (The Ministry of Sustainable Development's website from Environment and Parks is a useful source of information.)

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2. Why is polluted water detrimental to the environment?

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3. How is the level of water pollution measured?

Methods for water purification

There are two methods for purifying water: aerobic and anaerobic.

Aerobic: Air is injected into the water to oxygenate it and to promote the growth of micro organisms that will eat the suspended and dissolved solids. The micro organisms will grow and amalgamate then will be decanted to release clear, well oxygenated water. This technique is fast, but relatively costly.

Anaerobic: Polluted water is stored in hermetically sealed vats without the presence of oxygen to allow anaerobic micro organisms to grow and feed on the suspended and dissolved solids to produce biogas. Next, they will be decanted to release much less polluted water that will nevertheless need to be treated aerobically as described above. This technique is slower, but allows far more polluted water to be treated more economically and with the production of biogas.

Methanogenesis

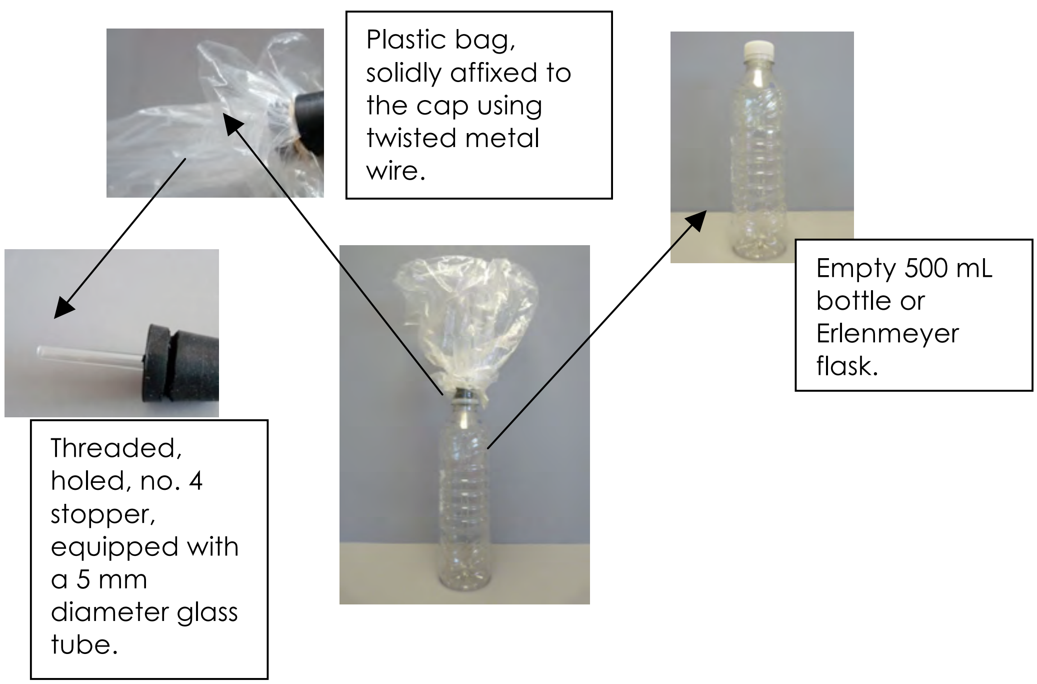
Suggestion of a short video sequence available on YouTube:
http://www.youtube.com/watch?v=bUBAndojs50

As we have mentioned previously, methanogenesis is a natural process. It is the product of exclusively anaerobic methanogenic bacteria. They are present in organic waste materials. In methanogenesis, however, several types of bacteria intervene. Three phases can be noted in the process. Each of these phases corresponds to the type and action of bacteria present.

Phase	**Type of bacteria**
Hydrolytic and fermentative	Acidogenic bacteria
Acetogenesis	Acetogenic bacteria
Methanogenesis	Methanogenic bacteria

Certain conditions are essential to the bacteria in order for the methanogenesis process to occur. The bacteria must be in a relatively Ph neutral environment (between 6 and 8). Also, there are three optimal temperature zones for bacterial activity. One is around 20°C (psychrophile zone), the second around 35°C (mesophile zone) and the third between 55 and 60°C (thermophile zone).

In order to grasp the process, carry out the following assembly:



Protocol:

1. Pour 450 mL of grape or apple juice into the bottle.
2. Add 2.0g of traditional yeast.
3. Empty the air from the bag by compressing it or by aspirating it with a syringe.
4. Install the stopper equipped with the bag on the bottle, ensuring the system is airtight.
5. Place on the counter for 24 to 48 hours.
6. Withdraw the bag, taking care to block the tube using a vinyl tube equipped with a clamp.
7. Identify the gas collected using known gas identification tests.

Results:

The gas gathered is ____________________ because____________________.

- This process is called **fermentation**. It is an anaerobic reaction, so it occurs ______________________________. It is a biochemical reaction of converted chemical energy contained in an organic molecule, in this case, _________________________ in another energy form by mushrooms, bacteria or ______________. These organisms transform ____________________________ into ______________________and into ___________________________.
- The ideal temperature for fermentation is between 35°C and 40°C.

Activate your neurons!

In the course of the last two school years, in your science and technology classes, you have studied the transformation of matter and more specifically, energy forms. Using your knowledge in these matters, answer the following questions.

1. What is combustion?

2. Enumerate and explain the transformation of energy forms implicated in lighting a light bulb in a house, using electricity obtained from the combustion of fossil fuels. (See diagram p. 17)

Explanations:

3. Using the information presented and resources you have consulted, do you think it would be useful to produce energy using biogases? Explain your answer.

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Exothermic and endothermic reactions

REMINDER: You have already noticed that matter can be transformed. Some changes occur without modifying either the nature or the characteristic properties of the matter. These are **physical changes.** Other types of changes imply the modification of the characteristic of the matter and by this very fact, their nature. These are **chemical changes.** Certain clues generally allow us to detect a chemical change. What are these clues?

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Directed laboratory

Observe different phenomena and complete the table below.

Phenomena	Type of transformation (chemical or physical)	Justification for the classification	Variation in temperature (increase, decrease or nil)
$Pb(NO_3)_{2(aq)}$ and $NaI_{(s)}$			
Ribbon of $Mg_{(s)}$ in a flame			

Water vaporisation			
Hot Paws			
Demonstration to be carried out under the hood! Mixture of $NH_4SCN_{(s)}$ and $Ba(OH)_2 \bullet 8H_2O_{(s)}$ in a beaker			
Emergency cold compresses			
Burning wood chips			
$Mg_{(s)}$ and $HCl_{(aq)}$			
Electrolysis of a solution of KI in the presence of phenolphthalein with carbon electrodes			
Solution of citric acid and $NaHCO_{3(s)}$			
Gaseous mixture containing CO_2 bubbling in lime water			

Conclusion:

Certain phenomena **require energy** while others **release energy** when they are produced. Let's also remember that temperature is an indirect measure of the average agitation of particles in a substance or the degree of heat present in this substance. The term "heat", however, is also called **thermal energy.** The variation in temperature observed therefore allows us to conclude either a **gain or loss of energy.**

In your opinion, when a decrease in temperature is noted, does the substance absorb or release energy? ______________________________

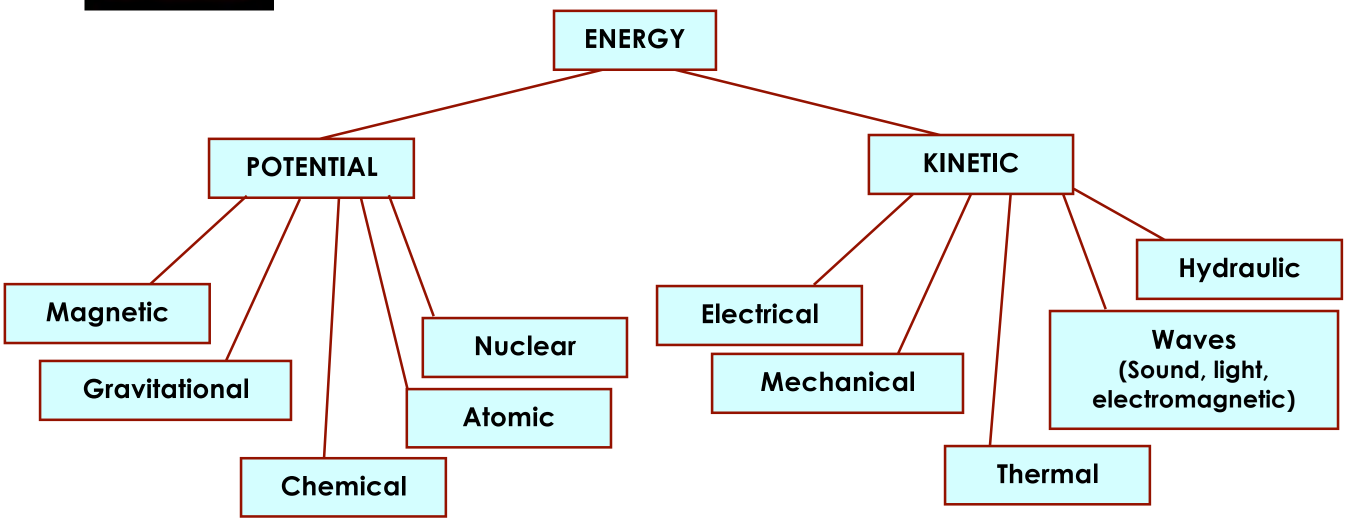
Conversely, when an increase in temperature is noted, does the substance absorb or release energy? ________________________________

- **Phenomena that absorb energy are called endothermic.** The prefix *endo,* which comes from Greek, means « interior or inside ». The word *endothermic* therefore means « heat inside or absorbed ».

- **Phenomena that release energy are called exothermic.** The prefix *exo,* which comes from Greek, means « outside or exterior ». The word *exothermic* therefore means « heat outside or released ».

Energy transformation and specific heat capacity

- REMINDER: Diagram of energy forms



Energy is an abstract but nevertheless very real concept that becomes tangible only by the effects it creates. In fact, a task is accomplished, a movement takes place, the temperature increases, a phase change occurs, a projectile reaches a target, etc. The unit of measure for energy is joule[6] (J).

- We speak of an **energy transfer** when energy passes from one substance to another. Energy may also go from one form to another, in which case we speak of an **energy transformation.**

Example: An alcohol burner is used to boil water. The alcohol molecules have a potential chemical energy that is released during combustion. This energy is transformed into kinetic energy by the molecules of the substances with which it comes into contact (air, container, water). These agitated molecules produce heat, thermal energy. Since they are in contact with one another, there is a transfer of enrgy from one substance to the other. The water molecules become agitated and acquire enough energy to pass from the liquid phase to the gas phase. The water

[6] James Prescott Joule was a British physicist (1818-1889). He is known for his research on mechanical labour and his theory of energy conservation. He also stated the relationship between heat dissipated by resistance traversed by an electrical current (Joule's Law). The unit of measure for energy now carries his name.

vapor molecules thus possess a greater amount of kinetic energy than liquid water. Vaporisation is therefore an endothermic physical phenomenon.

Specific heat capacity

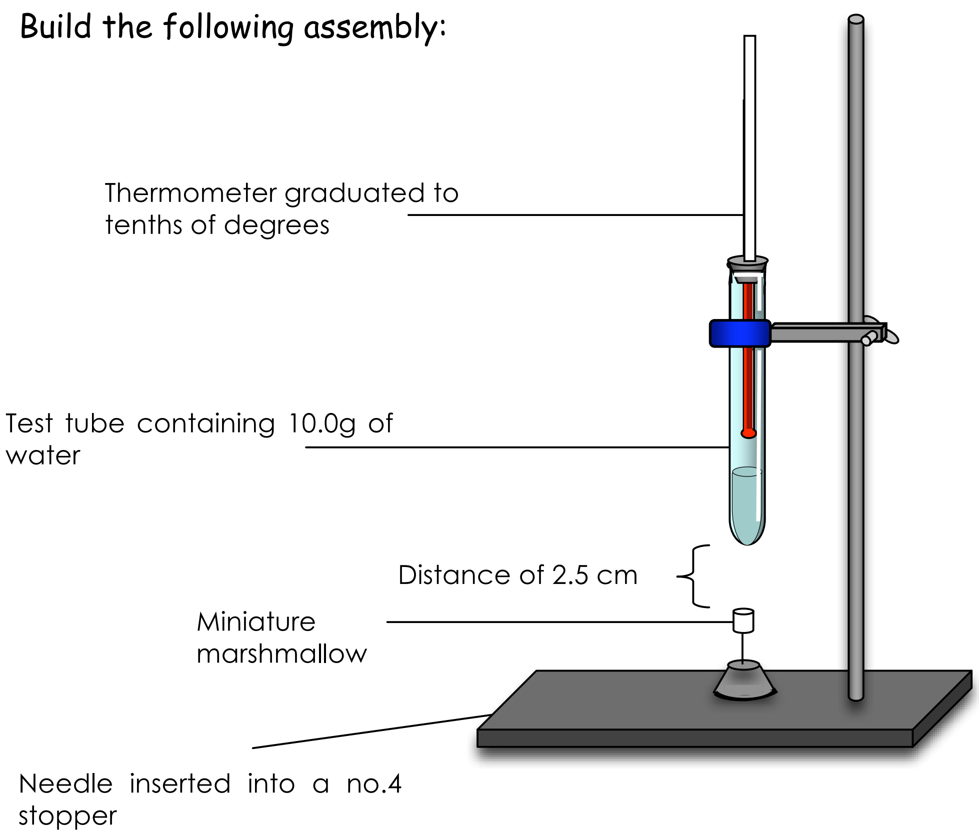
Do all substances heat and cool at the same speed? What is specific heat capacity? Could it be useful to us? How do we estimate its value?

We suggest a simple experiment that will allow you to find the answers to these questions.

Necessary material:

- Universal support
- Test tube support
- Thermometer
- 10.0 g of antifreeze
- 3 miniature marshmallows
- Needle
- 15 cm ruler
- Universal clamp
- 3 test tubes with holed stoppers
- 10.0 g of water
- 10.0 g of vegetable oil
- 1 no. 4 or bigger rubber stopper
- Matches
- Scale

Build the following assembly:



Protocol:

1. Build the assembly shown above.
2. Weigh 10.0g of water and place it in the test tube.
3. Install a miniature marshmallow on the needle ensuring a 2.5 cm distance between the top of the marshmallow and the bottom of the test tube.
4. Note the initial temperature of the water.
5. Light the marshmallow from underneath and let it burn until it goes out.
6. Note the final temperature of the water.
7. Repeat operations 2 to 6 using the vegetable oil and the antifreeze.

Results table:

Variation in the temperature of the liquid

Liquid	Initial temperature (± 0.05 °C)	Final temperature (± 0.05 °C)	Δ T (± 0,1 °C)
10.0 g of water			
10,0 g of vegetable oil			
10,0 g of antifreeze			

Questions:

1. Is the amount of energy supplied to each of the test tubes the same? Why?

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2. Can we affirm that each of the liquids received the same amount of energy?

---

3. Is the variation in temperature the same for the three liquids submitted to heating? Justify your answer.

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4. Is the quantity of each of the liquid the same?

Joseph Black, an 18th century Scottish chemist and physicist, had carried out a similar experiment. He thus deduced that substances of different natures, submitted to the same amount of heat, underwent different variations in temperature. He had given the term *heat capacity* to the **heat necessary to make a mass of 1g of a given substance vary 1°C.**

The name of this characteristic property has changed several times. It has gone successively from *heat capacity* to *specific heat* to finally be termed **specific heat capacity (c)** since the beginning of the 1990s.

Knowing that heat is thermal energy (Q) and the unit of measure for energy is joule (J); the unit of measure for specific heat capacity is J/g •°C.

Questions:

1. If 4.18J is necessary to increase the temperature of 1g of water by 1°C; what quantity of energy will be necessary to make a 1°C temperature variation in 8.0g of water?

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2. What quantity of energy will be necessary to make a 5°C temperature variation in 5.0g of water?

---

3. What would the quantity of water be if we notice an increase of 10°C while we supply 4180J?

---

4. What will the mathematical equation be to calculate the amount of heat or thermal energy (Q)?

Q=

5. Estimate the energy released by the combustion of a miniature marshmallow.

---

6. Round table discussion: is the heat released entirely transmitted to the water?

Chemical nomenclature and the chemical equation

To avoid confusion in science, the language used has been harmonised by adopting universal rules to name chemical elements and compounds. The *International Union of Pure and Applied Chemistry* (IUPAC) is the recognised authority as to the rules to adopt for nomenclature, symbols and terminology in chemistry.

It will be useful to become familiar with some of these rules in order to improve your comprehension while consulting reference sources and to more easily communicate between colleagues and experts. This knowledge may also be useful to accumulate points while playing certain board games!

1. Molecules formed by more than one atom of the same element:

We name the element by adding a prefix that informs us as to the number of atoms that make up the molecule.

Examples: Cl_2 is called dichloride.
H_2 is called dihydrogen.
P_4 is called tetraphosphorus.

Note: Certain substances are known by distinct appellations that are exceptions to these rules. These names are generally accepted and it is more useful to use the better known term. This is the case with O_3 which could be called trioxide, but which is better known by the designation of ozone.

Prefixes to know:

Proportion	**Prefix**
1	mono*
2	di
3	tri
4	tetra (tetr)
5	penta (pent)
6	hexa
7	hepta
8	octa
9	nona
10	deca

* When no ambiguity is possible the prefix mono may be omitted.

2. Binary composites:

The first element in a chemical formula is named first then the second element in the formula is named with the suffix *–ide* added to it. Prefixes are still used to indicate the proportion in which the element is found in the molecule.

Examples: NaCl is called sodium chloride.
$CaCl_2$ is called calcium dichloride.
PCl_4 is called phosphate tetrachloride.
$C0_2$ is called carbon dioxide*.

* As with all rules, there are some exceptions. Thus, with oxygen the term becomes oxide.

Some exceptions:

Oxygen = oxide
Sulphur = sulphide
Hydrogen = hydride
Nitrogen = nitride
Carbon = carbide

3. Composites including a polyatomic ion:

The atom that ends the molecule finishes with –o (oxygen becomes *oxo*) and the suffix *-ate* is added to the middle atom. As before, the first atom is named first. The rule as to prefixes continues to apply with respect to the proportions.

Examples: $CaCO_3$ is called calcium trioxocarbonate.
Na_2SO_4 is called disodium tetraoxosulfate
NaOH is called sodium hydroxide.*

* Several ions are designated differently; you must simply know them. You are required to know these two:

OH^- = Hydroxide
NH_4^+ = ammonium

Example: NH_4NO_3 is called ammonium trioxonitrate.

4. Molecule where the polyatomic ion is multiplied:
The ion is written in parentheses with the multiplier after it. The name of the ion is preceded by the terms bi, tri and tetra for two, three or four. The first element is named then the name of the ion is in brackets. The other rules continue to apply.

Examples: $Cr(OH)_3$ is called chromium tri (hydroxide).
$Ca_3(PO_4)_2$ is called tri calcium bi (tetraoxophosphate)

Now, can you apply these rules? Name the following molecules:

Chemical formula	**Name of the molecule**
HCl	
$Mg(NO_3)_2$	
O_2	
H_2SO_4	
NH_4I	
Fe_2O_3	
$PbNO_3$	
$CuSO_4$	
NaI	
H_3PO_4	

The chemical equation

In chemistry, in order to facilitate conversation and to simplify communication, the **chemical equation** is used **to represent chemical reactions.** You need only know a few basic rules to correctly translate a chemical reaction into a chemical equation.

- The substances that are put into contact or that react initially **(reagents)** to form new substances **(products)** are all expressed by their respective chemical formulae.
- The reagents are placed on the left side of the equation and the products, on the right.
- Coefficients are added to the chemical formulae to indicate the number of molecules involved in the reaction.
- An arrow indicates the transformation or the direction of the chemical reaction.

Example: Two dihydrogen molecules react with one molecule of dioxide to form two water molecules. This reaction is translated into:

$$2H_2 + O_2 \longrightarrow 2H_2O$$

- If a reaction is **exothermic**, it ______________energy. In the chemical equation, the energy is indicated on the side of the___________________ .
- If a reaction is **endothermic**, it ________________energy. In the chemical equation the energy is indicated on the side of the ___________________.

Exercices:

Translate the following chemical reactions by the appropriate chemical equation.

1) Under the action of heat, a molecule of calcium trioxocarbonate decomposes into calcium oxide and carbon dioxide.

---

2) A molecule of dihydrogen tetroxosulphate reacts with two molecules of potassium hydroxide to produce a molecule of dipotassium tetroxosulphate and two molecules of water, while dissipating heat.

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3) Energy is released while four molecules of iron oxidises in the presence of three molecules of dioxide and form two molecules of di-iron trioxide.

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4) The reaction of two molecules of carbon monoxide with a molecule of dioxide releases energy while producing two molecules of carbon dioxide.

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5) Carbon dioxide bubbles in a saturated solution of calcium trioxocarbonate (lime water) to produce calcium dihydrohide and water.

Stœchiometry and balancing a chemical equation

➢ REMINDER: Law of conservation of matter

Antoine Laurent de Lavoisier, an 18th century French chemist is renowned for his meticulous work in the study of gases. He was the first to elaborate what is now called the *scientific method.*

Today's chemists owe him many instrumentation tools in chemistry. He designed much more accurate scales than those that existed at the time, allowing him to pursue the research which brought him to the statement of the *law of conservation of matter:* "Nothing is lost, nothing is gained, and everything is transformed."

He demonstrated that substances react together in defined proportions to form new substances. During these reactions, the energy present in the molecules on each side of the equation is also conserved. The difference in energy between the reagent molecules and the products is translated into a surplus of energy on one side or other of the equation.

Balancing a chemical equation

A chemical equation must necessarily be balanced using **stœchiometric coefficients** to illustrate the proportions of the reagents and products.

In order for the equation to be balanced, we must necessarily find the same number of atoms of each kind on each side of the equation. For this to occur, only the use of coefficients is allowable. A reagent or product's chemical formula can never be modified since that would modify its very nature.

Examples:

1) $2\,H_2 + O_2 \longrightarrow 2H_2O$

Reagents	Products
2 x 2 = 4 atoms of H	2 x 2 = 4 atoms of H
2 atoms of O	2 atoms of O

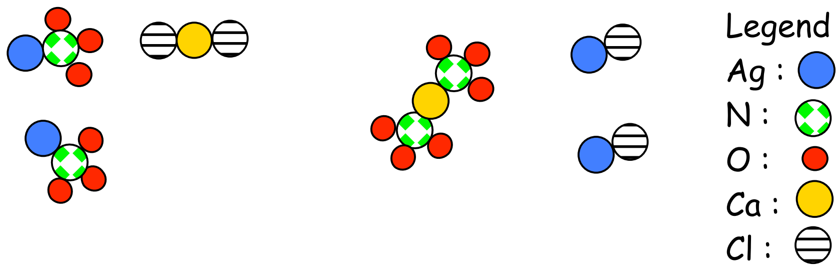
2) $2AgNO_3 + CaCl_2 \longrightarrow Ca(NO_3)_2 + 2AgCl$

Reagents	Products
2 atoms of Ag	2 atoms of Ag
2 atoms of N	2 atoms of N
2 x 3 = 6 atoms of O	2 x 3 = 6 atoms of O
1 atom of Ca	1 atom of Ca
2 x 1 = 2 atoms of Cl	2 x 1 = 2 atoms of Cl

Note that the stœchiometric coefficient multiplies the whole molecule while the index multiplies the atom or polyatomic ion that precedes it. Dalton's model is an interesting illustration of this principle.

Using equation (2) again:

$$2AgNO_3 + CaCl_2 \longrightarrow Ca(NO_3)_2 + 2AgCl$$



Exercises:

Balance the following chemical equations:

1. $Al + \quad Cl_2 \longrightarrow \quad AlCl_3$

2. $Al + \quad O_2 \longrightarrow \quad Al_2O_3$

3. $Fe_2O_3 + \quad CO \longrightarrow \quad Fe + \quad CO_2$

4. $S_8 + \quad O_2 \longrightarrow \quad SO_2$

5. $CaCO_3 + \quad NaCl \longrightarrow \quad Na_2CO_3 + \quad CaCl_2$

Write the balanced chemical equation for the combustion of gaseous carbon tetrahydrate (methane) in gaseous dioxide resulting in carbon dioxide and water vapour while releasing energy.

Study of the output of biogas: you are ready to take up the challenge!

We suggest that you undertake your research using two samples of gas.

In your own words, explain the challenge we have put to you and what you know about it.

Using your scientific knowledge, indicate what you intend to do to get there.

Draw up the list of materials necessary to your experimental research.

Write the experimental protocol you envisage.

Note and organise the data you have collected. Note and justify the adjustments made in the course of your experiment.

Using the data collected (by you and your colleagues), analyse your results in order to highlight the energetic output of the two samples. Explain your process.

What aspects of your experimental research could be improved upon? Justify your answer.

Write a short overview that outlines all the aspects of the proposed challenge. Your text must dwell on the following aspects:

- **Greenhouse effect**
- **Explanation of the process of methanogenesis**
- **Impacts of the exploitation of biogases**
- **Sustainable development and ecological footprint**
- **Energy transformation**

What have you learned? What do you retain from this learning and evaluation situation?

Annex 1

OUTIL DE CALCUL D'EMPREINTE ÉCOLOGIQUE PERSONNELLE

- Encercler le nombre de points qui correspond le mieux à vos habitudes.
- Compléter chaque rubrique en vous basant sur une journée ordinaire de votre quotidien.
- Additionner les points encerclés de chaque rubrique et noter la somme partielle pour la catégorie concernée.
- Reporter toutes les sommes partielles dans le sommaire, à la fin du questionnaire.

Section A - Consommation d'eau **Mes points**

1.
   - Je ne prends pas de douche ou de bain. (0)
   - Je prends une douche de une à deux minutes ou je remplis la baignoire au quart. (50)
   - Je prends une douche de trois à six minutes ou je remplis la baignoire à la moitié. (70)
   - Je prends une douche d'au moins dix minutes ou je remplis complètement la baignoire. (90)

2.
   - Je tire la chasse d'eau chaque fois que je vais aux toilettes. (40)
   - Je tire parfois la chasse d'eau quand je vais aux toilettes. (20)

3. Quand je me lave les dents, je laisse couler l'eau. (40)
4. J'ai lavé la voiture ou j'ai arrosé la pelouse aujourd'hui. (80)
5. Nous utilisons des toilettes économiques (6 – 9 litres par remplissage). (- 20)
6. Nous utilisons des pommes de douche à faible débit. (- 20)
7. Nous utilisons un lave-vaisselle au cours de la journée. (50)

Somme partielle (A) : __________

Section B - Alimentation

1. Au cours d'une journée, je mange en général :
   - Du bœuf (150/portion)
   - Du poulet (100/portion)
   - Du poisson d'élevage (80/portion)
   - Du poisson sauvage (40/portion)
   - Des œufs (40/portion)
   - Du lait/des produits laitiers (40/portion)

- Des fruits (20/portion)
- Des légumes (20/portion)
- Des féculents : pain, céréales, riz (20/portion)

2.

- Tous mes aliments sont cultivés localement. (0)
- Certains de mes aliments sont cultivés localement. (30)
- Aucun de mes aliments n'est cultivé localement. (60)

3.

- Tous mes aliments sont biologiques. (0)
- Certains de mes aliments sont biologiques. (30)
- Aucun de mes aliments n'est biologique. (60)

4.

- Je fais du compost avec mes restes et pelures de fruits et de légumes. (20)
- Je ne fais pas de compost avec mes restes et pelures de fruits et de légumes. (60)

5.

- Tous mes aliments sont préparés en industrie. (100)
- Certains de mes aliments sont préparés en industrie. (30)
- Aucun de mes aliments n'est préparé en industrie. (0)

6.

- Tous mes aliments sont emballés. (100)
- Certains de mes aliments sont emballés. (30)
- Aucun de mes aliments n'est emballé. (0)

7. Au cours d'une journée ordinaire, je (ne) jette :
   - Aucun aliment (0)
   - Un quart de mes aliments (100)
   - Un tiers de mes aliments (150)
   - La moitié de mes aliments (200)

Somme partielle (B) : ___________

Section C - Moyens de transport

1. En général, je circule :
   - À pied (0)
   - À bicyclette (5) par trajet
   - Dans les transports publics (30) par trajet

- Dans un véhicule privé (200) par trajet

2.

- Notre véhicule familial a une consommation de moins de 6 L/100 Km (-50)
- Notre véhicule familial a une consommation de 6 à 9 L/100 Km (50)
- Notre véhicule familial a une consommation 10 à 13 L/100 Km (100)
- Notre véhicule familial a une consommation de plus de 13 L/100 Km (200)

3. Le temps que je passe dans des véhicules chaque jour est :
   - Nul (0)
   - Moins d'une demi-heure (40)
   - Entre une demi-heure et 1 heure (60)
   - Plus d'une heure (100)

4. De quelle taille est la voiture dans laquelle je circule en général ?
   - Pas de voiture (- 20)
   - Petite (50)
   - Moyenne (100)
   - Grande (SUV, de type 4x4) (200)

5. Nombre de voitures à la maison?
   - Aucune (- 20)
   - 1 voiture (50)
   - 2 voitures (100)
   - Plus de deux voitures (200)

6. Dans une journée, je marche ou je cours :
   - 5 heures ou plus (- 75)
   - de 3 à 5 heures (- 25)
   - de 1 à 3 heures (0)
   - d'une demi-heure à 1 heure (10)
   - moins de 10 minutes (100)

Somme partielle (C) : __________

Section D - Logement

1. Nombre de pièces par personne : divise le nombre de pièces par le nombre de personnes dans ton foyer.
   - Moins de 2 pièces par personne (10)
   - De 2 à 3 pièces par personne (80)
   - De 4 à 6 pièces par personne (140)
   - 7 pièces ou plus par personne (200)

2. Nous partageons notre logement avec des gens qui n'appartiennent pas à notre famille. (- 50)

3.
   - Nous possédons une résidence secondaire qui est souvent inoccupée. (400)
   - Nous en partageons une résidence secondaire avec d'autres gens. (200)

Somme partielle (D) : __________

Section E - Consommation d'énergie

1. Au cours des mois les plus froids, la température de la maison est de :
   - Moins de 15°C (- 20)
   - 15 à 18°C (50)
   - 19 à 22°C (100)
   - 22°C ou plus (150)

2. Nous séchons les vêtements dehors ou à l'intérieur sur un séchoir.
   - Toujours (- 50)
   - Parfois (20)
   - Jamais (60)

3. Nous avons un réfrigérateur basse consommation d'énergie.
   - Oui (- 50)
   - Non (50)

4. Nous utilisons des ampoules fluocompactes.
   - Oui (- 50)
   - Non (50)

5. J'éteins la lumière, l'ordinateur et la télévision quand je n'en ai pas besoin.
   - Oui (0)
   - Non (50)

6. Pour me rafraîchir, j'utilise :
   - La climatisation dans la voiture (30)
   - La climatisation dans la maison (30)
   - Un ventilateur électrique (- 10)
   - Rien (- 50)

7. Temps passé à des activités extérieures ne nécessitant pas d'énergie (essence ou électricité) durant une semaine.
   - 7 heures (0)
   - 4 à 6 heures (10)
   - 2 à 3 heures (20)
   - 2 heures ou moins (100)

Somme partielle (E) : __________

Section F - Habillement

1. Je change de vêtements tous les jours et je les mets au lavage. (80)
2. Je porte des vêtements qui ont été raccommodés ou ajustés. (- 20)
3. Un quart de mes vêtements sont faits main ou d'occasion. (- 20)
4. J'achète la plupart de mes vêtements neufs tous les ans. (120)

5. Je donne à la boutique de vêtements d'occasion locale des vêtements que je ne porte plus.
   - Oui (0)
   - Non (100)

6. J'achète si possible des chemises en chanvre plutôt qu'en coton. (- 10)

7.
   - Je porte le quart des vêtements qui sont dans mon armoire. (100)
   - Je porte la moitié des vêtements qui sont dans mon armoire. (75)
   - Je porte les trois quarts des vêtements qui sont dans mon armoire. (50)
   - Je porte la quasi-totalité des vêtements qui sont dans mon armoire. (25)

8.
- J'ai 2 ou 3 paires de chaussures. (20)
- J'ai 4 à 6 paires de chaussures. (60)
- J'ai 7 ou plus paires de chaussures. (90)

Somme partielle (F) : __________

Section G - Matériaux divers

1. Toutes mes ordures de la journée tiendraient dans :
   - Une boîte à chaussures (20)
   - Un grand seau (60)
   - Une poubelle (200)
   - Je n'ai pas jeté d'ordures aujourd'hui ! (- 50)

2. Je réutilise les objets plutôt que de les jeter. (- 20)

3. Je répare les objets plutôt que de les jeter. (- 20)

4. Je recycle tout mon papier, mes boîtes de conserve, le verre et le plastique. (- 20)

5.
   - J'évite généralement d'acheter des articles jetables. (- 10)
   - J'achète régulièrement des articles jetables. (60)

6. J'utilise généralement des piles rechargeables. (- 30)

7. Ajoute un point pour chaque dollar que tu dépenses en moyenne par jour. (0)

Somme partielle (G) : ___________

Section H - Loisirs

1. Pour mes loisirs habituels, la superficie totale de terres transformées en terrains de jeu, patinoires, piscines, salles de gym, pistes de ski, parkings, etc., occupe :
   - Rien (0)
   - Moins d'1 hectare (100 ares) (20)
   - De 1 à 2 hectares / 100 à 200 ares (60)
   - 2 hectares ou plus / 200 ares ou plus (100)

2. Dans la journée, je me sers de la télé ou de l'ordinateur
   - Pas du tout (0)
   - Moins d'une heure (50)
   - Plus d'une heure (80)

3. De combien d'équipement ai-je besoin pour mes activités ordinaires ?
   - Aucun (0)
   - Très peu (20)
   - Un peu (60)
   - Beaucoup (80)

Somme partielle (H): __________

Sommaire

Reporte les sommes partielles de chaque rubrique et additionne-les pour obtenir la somme totale :

Section A - Consommation d'eau	______________
Section B – Alimentation	______________
Section C - Moyens de transport	______________
Section D – Logement	______________
Section E - Consommation d'énergie	______________
Section F – Habillement	______________
Section G - Matériaux divers	______________
Section H – Loisirs	______________
Somme totale :	______________

Somme totale $\div$ 100 = empreinte écologique exprimée en hectares.

Mon empreinte écologique est : _____________ hectares

L'hectare est une unité de mesure de superficie (ha) et correspond à 100 m x 100 m ou 10 000 m^2.

Note : Pour obtenir un résultat en ares, il faut multiplier la somme totale par 100. L'are est une unité de mesure de superficie (a) et correspond à 10 m x 10 m ou 100 m^2.

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http://www.methanisation.info/

ClimateChangeNorth.ca – Yukon conservation society web site
http://www.climatechangenorth.ca/section-BGF/

Planète Terre – Web site of Mr. Pierre-André Bourque and the Département de géologie et de génie géologique of the Université Laval à Québec.
http://www.ggl.ulaval.ca/personnel/bourque/intro.pt/planete_terre.html

Electrigaz – A company specialising in the study, design and realisation of biogas systems. Their offices are in Harrington, Quebec.
www.electrigaz.com

La Recherche – French language scientific information magazine.
http://www.larecherche.fr/content/recherche/

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http://www.greenteacher.com/francais.html

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