The Power System and Health

Electric and Magnetic Fields

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Abbreviations and symbols

EMF	electric and magnetic field
HVPL	high-voltage power line
kV	kilovolt (unit for measuring the voltage carried by an HVPL; 1 kV = 1,000 volts)
µT	microtesla (unit of measurement used for magnetic fields; 1 µT = 1 millionth of a tesla)
V/m	volts per metre (unit of measurement of electric field strength)

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Electric and magnetic fields: The data is reassuring

It's hard to imagine a world without electricity. And yet, wherever electricity is used, electric and magnetic fields (EMFs) are produced by electrical circuits and appliances. Although these fields are generally weak and imperceptible, their potential effect on the human body has been the subject of extensive studies for over 50 years. This research has led to the publication of numerous reports.

But what is an electric or magnetic field? How strong are the fields we are exposed to on a daily basis? And most important, what do we know about their effects on the human body and on our health? What is the opinion of public health authorities, both here and around the world? The purpose of this brochure is to answer these questions.

Today, electric and magnetic fields are much better understood and documented than they were a few years ago. As we will see, despite the growing number of studies done on EMFs and the increasing quality of those studies, researchers have been unable to show any effect on human health, whether from EMFs in the workplace or at home — which is reassuring.

As for the hypothesis, first put forth in 1979, of a possible link between childhood leukemia and extremely low-frequency magnetic fields in the home, it has never been confirmed despite extensive experiments and epidemiological research. It is most likely a false alarm.

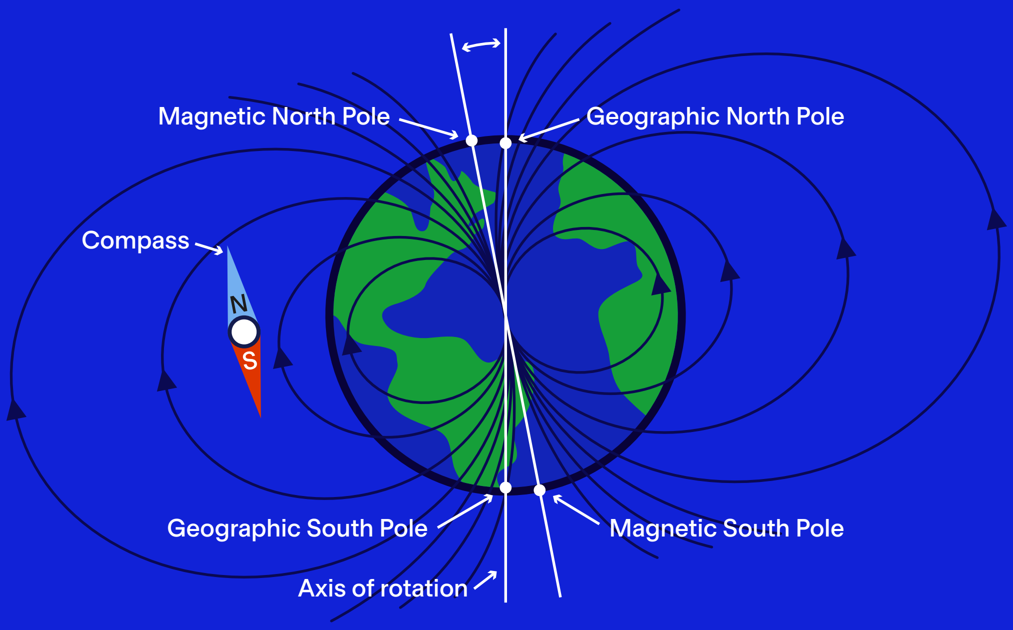
Yours truly,

Dr. Michel Plante
Direction principale – Santé et sécurité
Hydro-Québec

Electric and magnetic fields

Electric and magnetic fields (EMFs) are all around us, occurring naturally in every atom of matter. The surface of the Earth is covered with a natural electric field, created by electrical charges in the upper atmosphere. Similarly, a powerful electric field is required to keep the cells of living organisms alive.

The Earth is also surrounded by a magnetic field that can be detected with a compass. This magnetic field is generated by the electrical currents produced by the movement of molten matter in the Earth's core. This movement, which is nearly constant, generates direct current. The electricity produced by Hydro-Québec's generating stations and used to power our appliances and other devices is different. In the latter case, the electrons that move to create the electrical current change direction regularly, at a rate of 60 cycles per second. This is what we call a 60-hertz alternating current, which produces alternating EMFs.

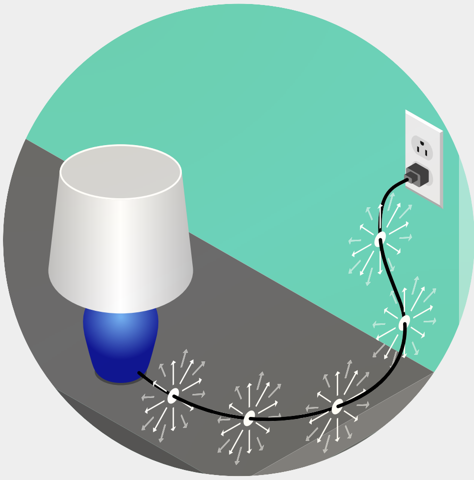


What is an electric or magnetic field?

All uses of electricity generate an electric field and a magnetic field. These fields are strongest near the source, becoming weaker with distance. The notion of a "field" also applies to other physical phenomena present in our everyday environment.

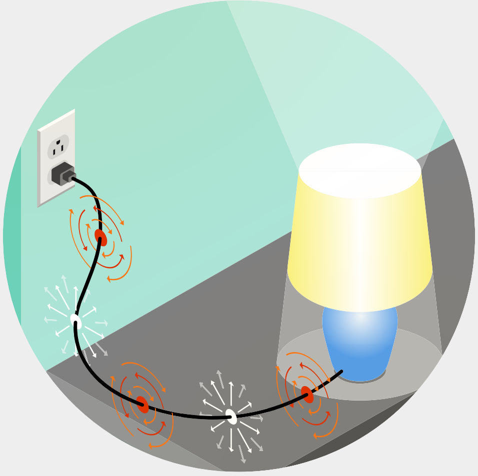
Although the analogy is not scientifically exact, you could compare an EMF to the heat coming from a campfire. The temperature is very high near the fire, dropping quickly as you move away. Past a certain distance, depending on the size of the fire, you will no longer feel any heat from it.

Lamp plugged in, but switched off (120 V)
Electric field only



An electric field is related to voltage (expressed in volts). It is generated by the presence of electrical charges (electrons) and is measured in volts per metre (V/m). The higher the voltage supplied to an appliance, the stronger the resulting electric field. Around the cord of an appliance plugged into a socket, an electric field is generated, even if the appliance is not switched on. The strength of this field can be substantially reduced by anything that acts as a screen, such as trees, fences and buildings.

Lamp switched on (120 V, 1A)
Electric and magnetic fields



A magnetic field, on the other hand, is generated by electric current (expressed in amperes); that is, by the movement of electrons. This means that only devices that are switched on create a magnetic field, and this field disappears once a device is turned off. Unlike electric fields, magnetic fields are not reduced by trees, fences or buildings, as magnetic fields pass easily through solid matter. The strength of a magnetic field is measured in teslas, although more often a much smaller unit, the microtesla (μT), will be used. One microtesla is one millionth of a tesla.

What factors contribute to my exposure to EMFs?

We are all exposed to EMFs produced by electrical appliances, the household circuits that power them, and the transmission and distribution lines that bring electricity into our homes. The extent of our exposure is largely determined by how close we are to such equipment.

As we have seen, all electrical equipment produces both an electric and a magnetic field when in operation.

The electrical energy that we use at home is provided at a low voltage, resulting in an electric field that is only a few volts per metre. The place where the electric field is strongest is directly under high-voltage power lines, where the conductors are closest to the ground. There is also a natural electric field in the air, which gets stronger just before and during a storm.

Ambient magnetic fields in Québec homes are very weak and rarely exceed 1 μT. However, their strength can differ substantially from one home to another. At our latitude, the Earth's magnetic field is around 50 μT. Unlike the EMFs produced by power equipment, natural EMFs (like the Earth's magnetic field) do not consist of alternating current; they are static fields.

Many ordinary electrical appliances produce a magnetic field of tens or even hundreds of microteslas. Some specialized equipment used in hospitals emit significantly stronger magnetic fields—on the order of the tesla in the case of magnetic resonance imaging (MRI) scanners. However, the strength of the field decreases considerably as you move away from the source and an appliance used for a short period of time doesn't contribute much to your overall exposure.

In the home

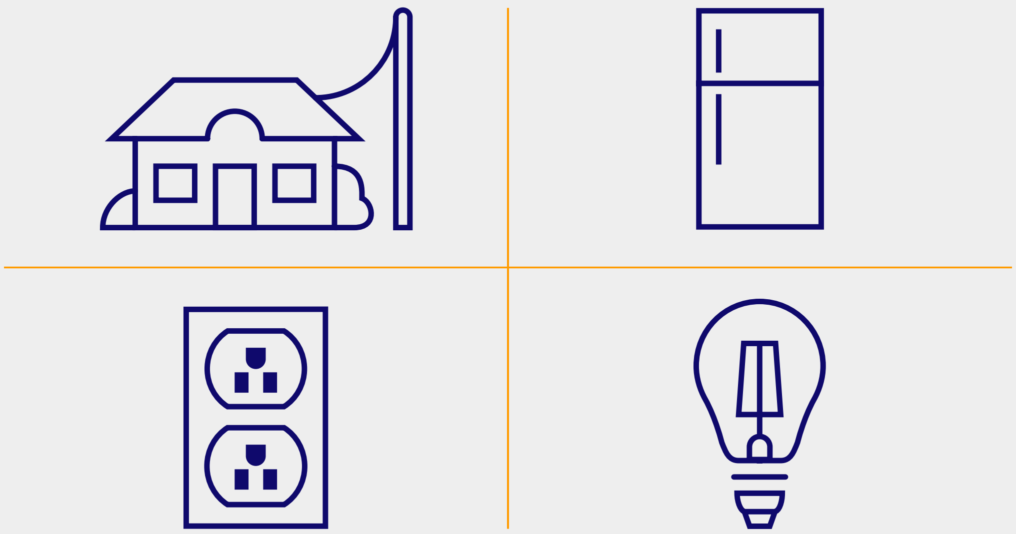
Many factors contribute to the ambient EMFs in your home: how long electrical appliances are in use, the amount of current circulating in the ground wire of your electrical distribution panel, power consumption in your neighbourhood, the distance between your house and the next and between your house and the power system, etc.

The electrical field changes very little and it is weak enough to be imperceptible. The walls and roof of your home make for an effective screen that reduces the electric field produced by outside equipment—for example, by power lines. The 60-Hz electrical field inside the home generally ranges between 1 and 10 V/m, at a distance from electrical appliances.

Conversely, the magnetic field strength in most homes varies according to a cycle, which is determined by your power usage and that of your neighbours.

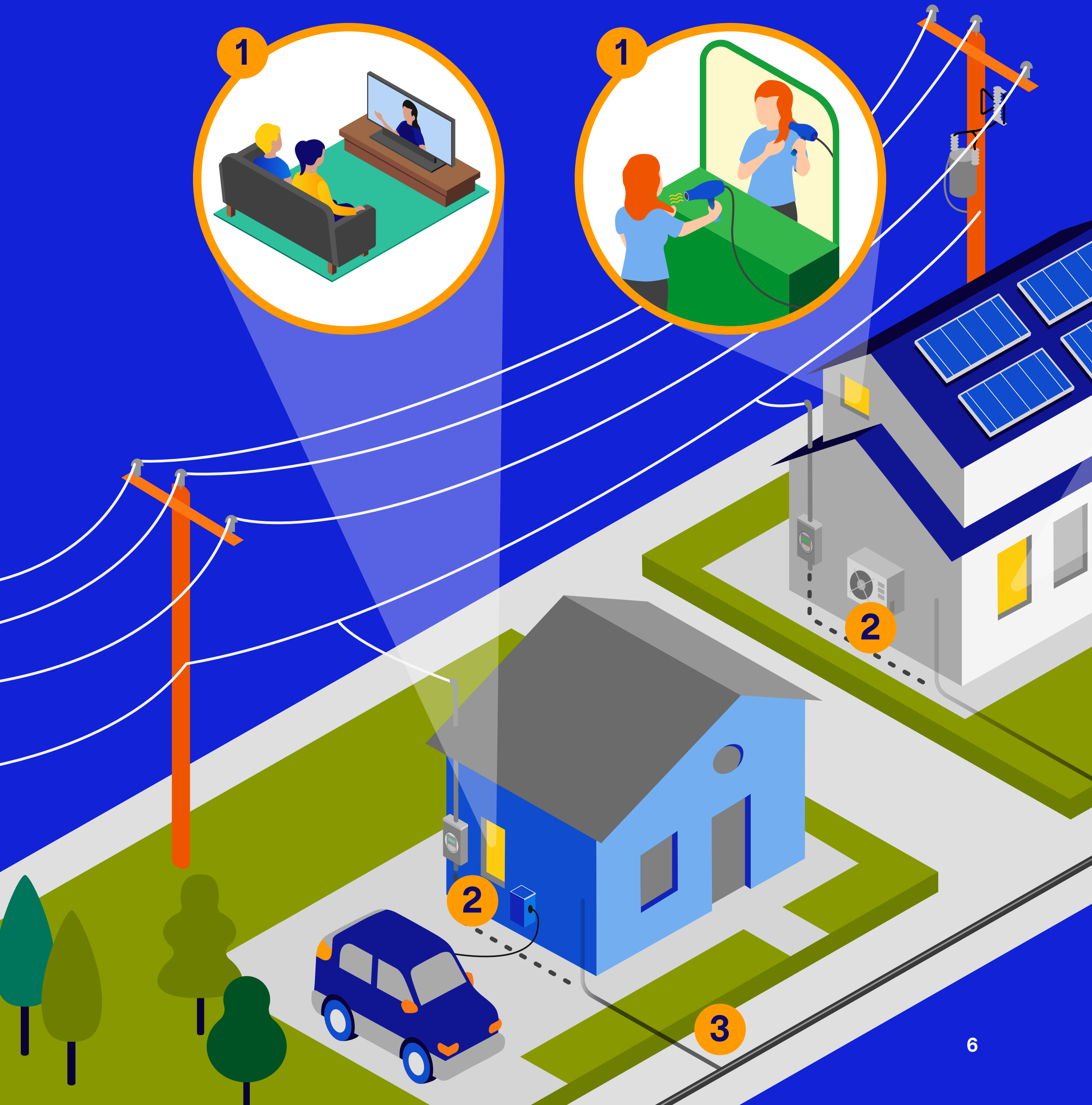
The magnetic field generally peaks between 6 p.m. and 8 p.m. and is at its weakest when people are asleep and most activity has ceased. This rule of thumb usually holds true for your immediate neighbours and for the entire area. In addition to a daily cycle, there are also seasonal variations. The strength of a 60-Hz magnetic field inside the home generally ranges between 0.1 and 0.3 μT, at a distance from electrical appliances.

The table on page 7 gives you an idea of average magnetic fields for some common electrical appliances. As you can see, some devices generate stronger magnetic fields than others.



1 Your exposure to the magnetic field of an appliance that is turned on is determined by how close you are to it.

2 Your distribution panel is usually grounded to your home's water main to protect you from electric shock or electrocution in the event of an appliance malfunction.



3 Because the houses on your street probably have their grounding systems connected to the water supply system, you could say that they are all on the same electrical circuit. In fact, a number of studies have shown that the current in the grounding system is the main factor contributing to the ambient magnetic field in our homes.

EMFs in our homes

Average magnetic field of common appliances and devices (μT)

	Distance from source		
	15 cm	30 cm	1.2 m
Iron	0.8	0.1	–
Dishwasher	2.0	1.0	–
Electric stove element	3.0	0.8	–
Straight-tube fluorescent light	4.0	0.6	–
Electric mixer	10.0	1.0	–
Microwave oven	20.0	1.0	0.2
Circular saw	20.0	4.0	–
Hair dryer	30.0	0.1	–
Vacuum cleaner	30.0	6.0	0.1
Electric can-opener	60.0	15.0	0.2
Photocopier	90.0	20.0	1.0

	1 cm
Conventional electric blanket	10.0
Electric shaver	800.0

Source: *EMF In Your Environment: Magnetic Field Measurements of Everyday Electrical Devices* Environment Protection Agency, United States, 1992.

Near the distribution system

The power distribution system is the primary source of EMFs outside the home, because it brings electricity into your neighbourhood, right to where you live. In most cases, the electric fields created by distribution lines don't vary much because of their relatively stable voltage of 25 kV for a three-phase circuit and 14 kV for a single-phase circuit. Also, since the walls of your house act like a screen, these power lines contribute very little to the electric field inside your home.

Magnetic fields measured near power lines vary according to season, power demand and the technical characteristics of the lines (for example, pole height). Even underground distribution lines produce EMFs, since the magnetic field passes easily through matter, whether earth, rock or concrete.

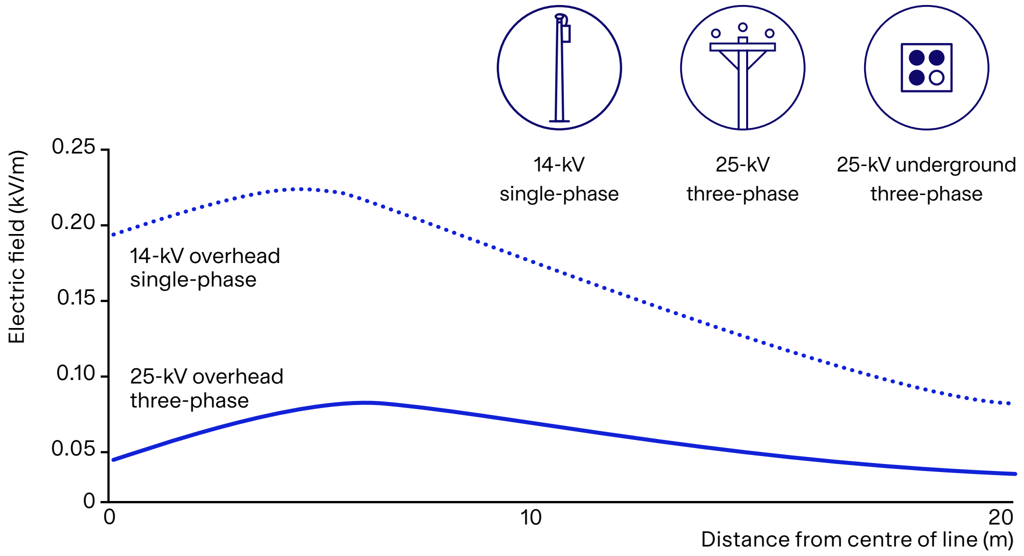
The transformer myth

Since transformers are often perceived as a source of strong magnetic fields, measurements were taken close to distribution transformers. It was found that most of these units do not contribute to a power line's magnetic field past a distance of about two metres. Why? To optimize efficiency, transformers are designed to concentrate the magnetic field right in their core.

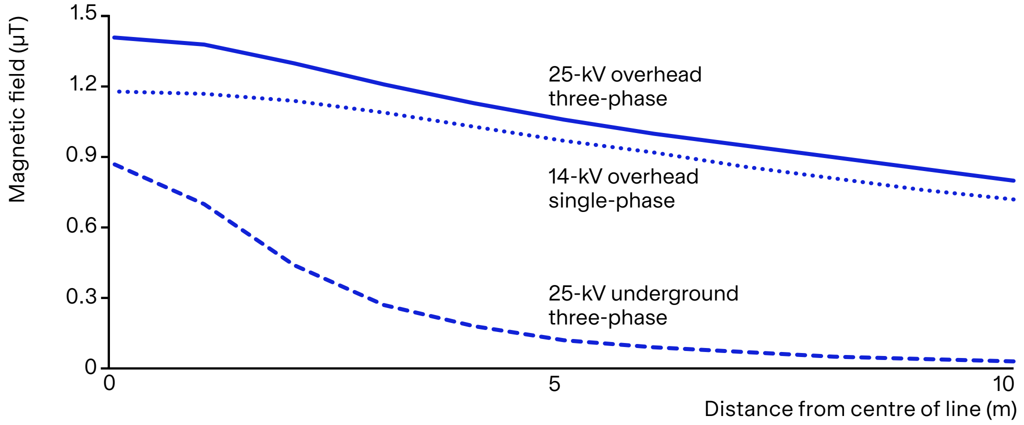
When distribution lines are underground, pad-mounted transformers are used. These are the cabinets you see sitting on concrete bases. At one metre from a pad-mounted transformer, the magnetic field generated by the device drops to the ambient level produced by the underground line supplying it.

The two graphs below show EMF measurements based on distance from the centre of a single-phase overhead line at 14 kV and an overhead three-phase line at 25 kV. The magnetic field measurements of an underground three-phase line at 25 kV are also presented.

Electric field generated by distribution lines (kV/m)



Magnetic field generated by distribution lines (µT)



Note: The magnetic field values shown here are based on numbers that are higher than the provincial averages, to better represent the reality of densely populated urban centres. Fields can vary according to the technical characteristics of each line: pole height, normal variations in line current, conductor or cable configuration, etc. Underground lines do not generate an electric field.

Near high-voltage power lines

Much like distribution lines, high-voltage power lines (HVPLs) produce an electric field that changes very little because of the lines' stable voltage. This electric field gets weaker the farther you get from the line.

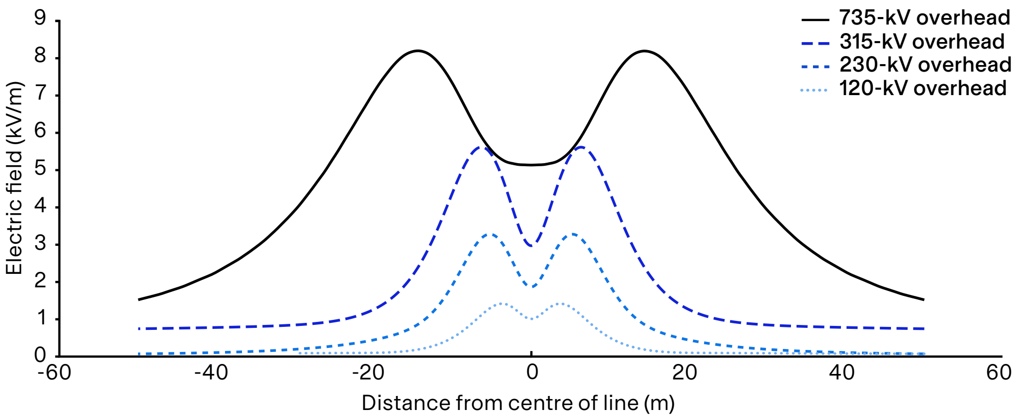
As for the magnetic field, since its strength depends not only on the intensity of the electric current but also on the distance from the source, the magnetic field generated by an HVPL is strongest directly beneath the line and drops sharply as you move away. Note that only the wires carrying electric current produce a magnetic field; the towers that support these wires do not because there is no current flowing in them.

Beyond a distance of about 100 m from the right-of-way of a 735-kV HVPL, the magnetic field strength generally falls to the level of the ambient field produced by other sources in the environment.

Since Quebecers use more electricity in winter—mainly to heat their homes—the current carried on HVPLs varies considerably from season to season. The magnetic fields of HVPLs will therefore be at their strongest during the coldest periods of the year and drop during the summer.

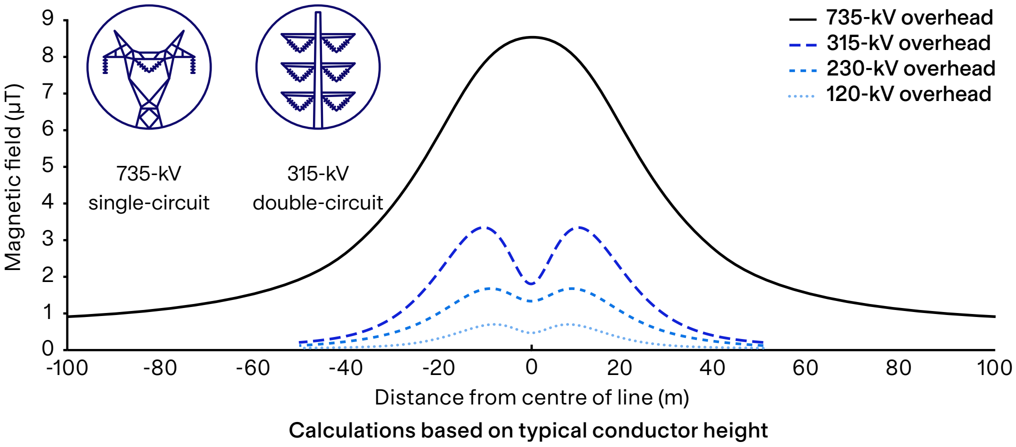
The diagram below gives an idea of the average EMF values obtained near typical HVPLs under normal operating conditions, measured by convention at one metre above ground level.

Electric field generated by HVPLs (kV/m)



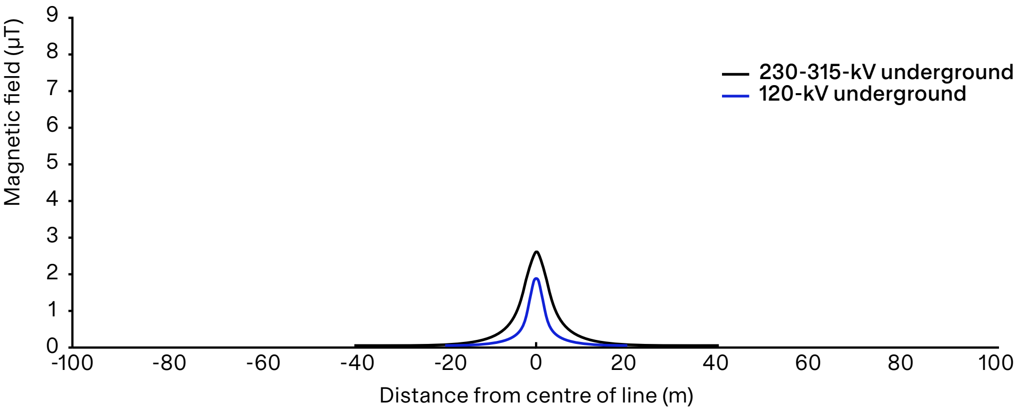
Fields are calculated at 1.5 m above the minimal conductor height.

Magnetic field generated by HVPLs (µT)



The diagram below gives an idea of the magnetic fields measured near underground HVPLs.

Magnetic field generated by underground HVPLs (µT)



Note: The magnetic field values shown above are based on average currents measured in most lines of each type. Fields can vary according to the technical characteristics of each line: pole height, normal variations in line current, conductor or cable configuration, etc. Underground lines do not generate an electric field.

Near substations

At most urban substations, the magnetic field measured at the fence does not exceed the ambient level.

On the whole, the equipment within the substation yard contributes very little to the magnetic field measured outside the substation.

The lines leading into and out of the substation account for most of the EMFs measured there.

What is the crackling noise sometimes heard under an HVPL?

This phenomenon, called the corona effect, occurs when the electric field, which is extremely strong near conductors, generates a cloud of tiny electric discharges in the air. Although it is a very localized phenomenon and does not extend any further than a few centimetres from the conductors, the corona effect can become more pronounced in poor weather and make a faint crackling noise. It can also cause radio interference if you drive a car under the line.

What do we know about the effects of EMFs on health?

For nearly 50 years now, scientists have been investigating the possible effects of EMFs on human health. Hundreds of epidemiological studies have been conducted on various groups, including electric utility workers and the general public. In addition, numerous laboratory studies have been carried out to study the effects of these fields on living cells, various animal species and humans.

The extraordinary number of studies on EMFs—a few hundred of which have been devoted to cancer—has allowed for excellent documentation of how harmless these fields are at the exposure levels typically found in our homes and workplaces. In particular, no evidence has been found to confirm the hypothesis of a link between residential-level magnetic fields and childhood leukemia. In view of the large number of high quality experimental studies conducted, we can now reasonably conclude that this hypothesis is very likely a false alarm.

The presence of a 60-Hz EMF causes the electrical charges within the body to move and alternate at the same frequency: 60 oscillations per second. This phenomenon produces little electric currents within the body that disappear as soon as the person is no longer exposed to the field. These microcurrents do not accumulate within the body and they are generally imperceptible since they are not strong enough to stimulate nerve and muscle tissue. They are also weaker than the natural currents produced by your heart and brain. For example, under the influence of a magnetic field of 0.15 μT, the microcurrents produced in your body are about 5,000 times weaker than your body's natural currents.

Magnetic fields

The first effects of 60-Hz magnetic fields on humans do not appear until the level exceeds 15,000 μT, a very high intensity that has only been achieved in laboratory situations. Exposure to such a field produces microcurrents in the retina that are then sent to the brain via the nervous system, which gives us the impression of seeing flashes of a diffuse white light called magnetophosphenes. These flashes, which are not painful and do not damage eyesight, cease as soon as exposure to the field ends.

As for the threat of cancer, experiments have been conducted on isolated cells and tissues, as well as long-term studies on animals at exposure levels 25,000 times higher than the average levels in the home. None of these experiments have indicated that 60-Hz magnetic fields have carcinogenic effects. The findings of epidemiological studies are also reassuring. And as regards childhood leukemia, studies based on actual measured magnetic fields in homes have not established any causal relationship.

Magnetic fields of 60 Hz have no effect on pregnancy or fetal development, according to experimental studies on isolated cells and tissues as well as long-term studies on animals at exposure levels 25,000 higher than average residential levels. This is further confirmed by numerous studies carried out on animals and people, including studies of electric utility workers and children, which have added to the evidence that alternating magnetic fields are not harmful to pregnant woman or their unborn children.

In addition, none of the epidemiological studies could establish a link between exposure to 60-Hz magnetic fields and a higher risk of cardiovascular disorders, depression, suicide, amyotrophic lateral sclerosis, multiple sclerosis, Alzheimer's disease or Parkinson's disease.

Hypersensitivity to EMFs

A number of individuals experiencing health concerns, including disabling symptoms, believe their issues are caused by exposure to a variety of EMF sources. A wide range of symptoms are attributed to "electromagnetic hypersensitivity" (EHS), and these vary from one person to the next. Currently, there are no set clinical criteria defining this condition, which is not recognized as a diagnosis by the medical community. According to Health Canada, "there is no scientific evidence that the symptoms attributed to EHS are indeed caused by exposure to EMFs."

Explanation of microshocks

When your body is exposed to an electric field, it becomes charged with static electricity, creating a similar effect to when you drag your feet across a carpet in dry weather. Then, when you touch an object, there is a small electric discharge that allows your body to release the excess electric charge. These microshocks can be startling. If the field is stronger than 5,000 V/m, they even become unpleasant and in fields over 10,000 V/m, they can be painful. And yet microshocks are not dangerous because they last such a short time (less than one millionth of a second) and because the excess charge that causes them is right at the skin's surface and does not impact your internal organs.

Fluorescent tubes under HVPLs: An amazing but harmless phenomenon

When a person holds a fluorescent tube by one end under a high-voltage power line, it emits a weak light. Why does this happen?

The line's electric field creates a weak electric current in the tube, measured in millionths of an ampere. The gas inside the tube, excited by the current, gives off light. A similar phenomenon can be observed when a fluorescent tube is held close to a car's spark plug wires. The phenomenon has no effect on living organisms.

Electric fields

Most people feel the first effects of electric fields only at levels rarely reached in daily life. For 60-Hz alternating currents, the field is imperceptible until it reaches a level of 3,000 V/m, where it may produce a tingling sensation. At 6 to 7 kV/m, the sensation starts to get uncomfortable. At 10,000 kV/m, the microshocks may be painful, but are not dangerous. This is the level at which you can feel a current flowing through your body if you touch a large metal object such as a car.

At 20,000 V/m, the microshocks are sufficiently unpleasant to warrant wearing a safety suit, like those worn by employees who work on HVPLs.

Experimental studies conducted on animals have not reported any serious effects at electric field levels of 30,000 V/m, which is three times higher than the maximum level measured under a 735-kV line. In humans, acute or prolonged exposure to electric fields has no adverse effect on health.

You're riding your bike under an HVPL and you suddenly feel small electric shocks (microshocks) as you touch your handlebars or the frame of your bike…

The balance has just been restored between your body's electrical charge and that of your bike's metal parts. An HVPL's electric field creates a charge in your body, and a different charge in the metal of your bike. When you touch the metal parts, these electrical charges are instantly brought to the same level, producing a microdischarge that may be unpleasant but is not harmful.

To avoid the discharge, just touch the metal of your handlebars as you near the power line, and maintain contact as you pass under the line. Your bike and your body will then behave as a single unit, which will eliminate the difference in electrical potential, allowing you to avoid the microshock.

Explanation of the tingling sensation on the skin

When your body is exposed to an electric field, it builds up static electricity. The electric charges accumulate only at the surface of your skin and hair. At field levels of 1,000 V/m, the charge is strong enough to make your hair vibrate. This phenomenon can be felt by very sensitive people when the weather is dry and there is no wind. However, the electricity remains on the surface of your skin and poses no danger to your health.

Under an HVPL, your body becomes electrically charged. For example, in an electric field of 10,000 V/m, the human body accumulates an electric charge of a few thousand volts, enough to make the hairs on your skin vibrate. This is similar to the effect of a Van de Graaff generator, which can produce several hundred thousand volts of electricity, making your hair stand on end. The spectacular effects of this machine can be observed at some interpretation centres, including Hydro-Québec's Électrium.

Opinion of public health authorities

Ministère de la Santé et des Services sociaux (2014)

A scientific committee on electromagnetic fields was established at the request of Québec's Ministère de la santé et des Services sociaux (MSSS) and its public health network. The committee, made up of experts from the MSSS, the Institut national de santé publique du Québec (INSPQ) [Québec's national institute for public health] and regional public health branches, published a position that states the following [translation from the original French]: "The Scientific Committee on EMFs considers that the overall evidence does not support the conclusion that adverse health effects result from exposure to extremely low frequency (ELF) electric and magnetic fields (EMFs) at levels typically found in the environment. [...] There is no scientific basis for adopting an exposure limit to extremely low frequency (ELF) electric and magnetic fields (EMFs) that would be lower than established guidelines or standards. Therefore, the Committee is proposing neither an exposure limit to magnetic fields, nor a minimal distance to be maintained from an exposure source, nor an exclusion zone for new constructions of certain facilities (hospitals, daycares, etc.) near high-voltage power lines (HVPLs)."

Health Canada (2024)

"The potential health effects of extremely low frequency EMF has been studied extensively. While some people are concerned that long term exposure to extremely low frequency EMF may cause cancer, the scientific evidence does not support such claims. [...] Extremely low frequency EMF exposures in Canadian homes, schools and offices are far below the limits recommended in the ICNIRP guidelines. You don't need to take precautions to protect yourself from these kinds of exposures."

World Health Organization (WHO) (2024)

"At low frequencies, external electric and magnetic fields induce small circulating currents within the body. In virtually all ordinary environments, the levels of induced currents inside the body are too small to produce obvious effects. [...] Despite extensive research, to date there is no evidence to conclude that exposure to low level electromagnetic fields is harmful to human health."

Are there EMF exposure standards?

In Québec and Canada, there are no regulations or laws that limit public or worker exposure to 60-Hz EMFs.

Internationally, two influential scientific organizations recommend limits on human exposure to EMFs. These are the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE). ICNIRP's mission is to analyze the risks of non-ionizing radiation on human health. In cooperation with the WHO, it formulates recommendations on exposure limits for workers and the general public. The IEEE is an international professional association that is responsible for developing safety standards, among other things. To be applied in a given country or jurisdiction, recommendations from either organization must first be adopted as a regulation or law.

EMF measurements conducted in Québec show that **outside** HVPL rights-of-way, the fields measured do not exceed the limits recommended by ICNIRP or IEEE. However, the electric field levels recommended by the ICNIRP may sometimes be exceeded **within** the rights-of-way of some lines, for example, 735-kV HVPLs, when a person stands directly under the wires at their lowest point, midway between two towers. The electric field levels recommended by the IEEE are not exceeded. In fact, IEEE allows up to 10 kV/m under HVPLs.

Exposure limits to 60-Hz electric fields

	ICNIRP (kV/m)	IEEE (kV/m)
Workers	8.3	20
Public	4.2	5[a]

a. 10 kV/m under HVPLs

Exposure limits to 60-Hz magnetic fields

	ICNIRP (μT)	IEEE (μT)
Workers	1,000	2,710
Public	200	904

Websites

Hydro-Québec
https://www.hydroquebec.com/fields/

International Commission on Non-Ionizing Radiation Protection
https://www.icnirp.org/

MSSS (information in French only)
https://publications.msss.gouv.qc.ca/msss/fichiers/2014/14-208-01W.pdf

World Health Organization
https://www.who.int/news-room/questions-and-answers/item/radiation-electromagnetic-fields

Health Canada
https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/everyday-things-emit-radiation/power-lines-electrical-appliances.html

To find out more about EMFs

Contact the Électrium

2001, rue Michael-Faraday, Sainte-Julie (Québec)
Telephone: 1-800-267-4558 or 450-652-8977 (Montréal area)

Website:
https://www.hydroquebec.com/facility-tours/tours-general-public/electrium-monteregie.html

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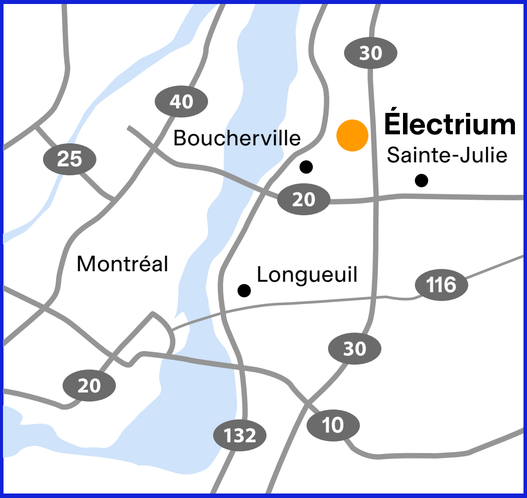

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