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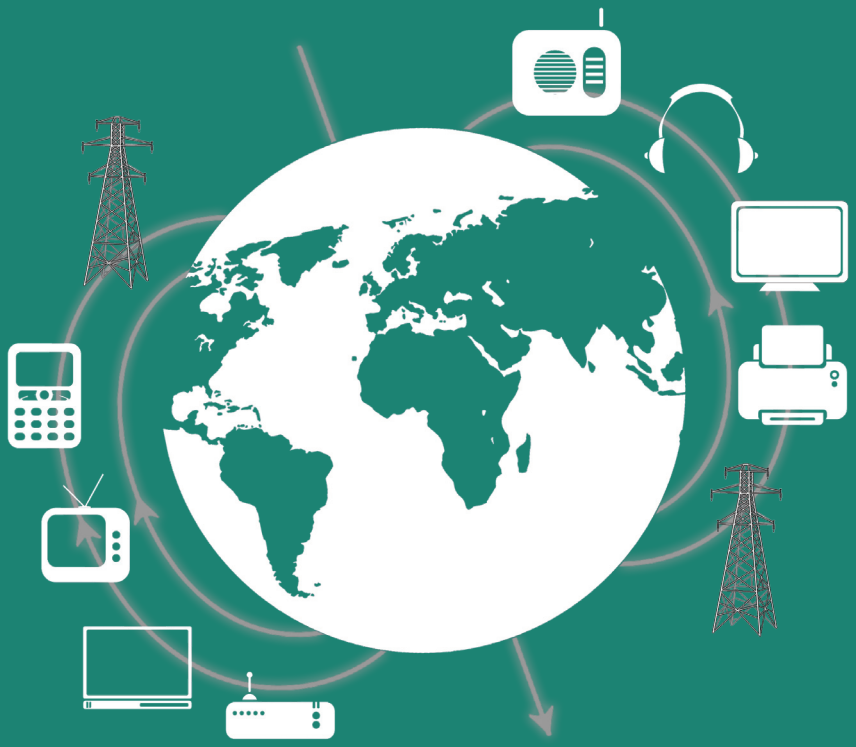
electric and **magnetic** fields

energy**networks** association

the facts



Electricity plays a central role in the quality of life we now enjoy. In particular, many of the dramatic improvements in health and safety that we benefit from today could not have happened without a reliable and affordable electricity supply. Electric and magnetic fields (EMFs) are present wherever electricity is used, in the home or from the equipment that makes up the UK electricity system.

But could electricity be bad for our health? Do these fields cause cancer or any other disease?

These are important and serious questions which have been investigated in depth during the past three decades. Over £300 million has been spent investigating this issue around the world. Research still continues to seek greater clarity; however, the balance of scientific evidence to date suggests that EMFs do not cause disease.

This guide, produced by the UK electricity industry, summarises the background to the EMF issue, explains the research undertaken with regard to health and discusses the conclusion reached.

Electric and Magnetic Fields

Electric and magnetic fields (EMFs) are produced both naturally and as a result of human activity. The earth has both a magnetic field (produced by currents deep inside the molten core of the planet) and an electric field (produced by electrical activity in the atmosphere, such as thunderstorms).

Electric and magnetic fields are inherent in the laws of physics.

Wherever electricity is used there will also be electric and magnetic fields. This is inherent in the laws of physics - we can modify the fields to some extent, but if we are going to use electricity, then EMFs are inevitable.
Like many other things that we encounter in nature, EMFs can be harmful at high-enough levels. But the fields required, for example, to start interfering with the body's nervous system are much greater than those produced by the UK electricity system.

Fields of Different Frequency

A key characteristic of a field is the frequency. The frequency indicates how rapidly the field changes direction backwards and forwards, and is measured in hertz (Hz). The earth's magnetic and electric fields do not oscillate at all. They are known as 'static fields' and have a frequency of 0 hertz.

The electricity systems in the UK and the rest of Europe produce fields of 50 hertz; in North America the frequency is 60 hertz. It is these fields produced by the electricity system (known as 'extremely low frequency' (ELF) or 'power frequency' fields) that are discussed in this guide.

This guide does not cover TV, radio or mobile phones.

Other technologies use higher frequencies. For instance, TV and radio broadcasts operate at thousands or millions of hertz, while mobile phones transmissions are at around a billion hertz. Because these frequencies are so different and the science of the fields and their effects at those frequencies is also different, this guide does not cover those technologies.

The Difference Between Electric and Magnetic Fields

The Two Components

The term 'EMFs' encompasses two different though related concepts: electric fields and magnetic fields.

Electric Fields

Electric fields are produced by voltage. Voltage is the pressure behind the flow of electricity. It can be likened to the pressure of water in a hose. Electricity in UK homes is at a voltage of 230 volts (V), but outside homes it is distributed at higher voltages, from 11,000 volts (usually written 11kV) up to 400,000 volts (400 kV). Generally, the higher the voltage, the higher the electric field. Electric fields are measured in volts per metre (V/m).

Voltage can be likened to the pressure of water in a hose.

Magnetic Fields

Magnetic fields are produced by current, which is the flow of electricity. Current, which is measured in amperes or amps, can be likened to the flow of water in a hose when the nozzle is open. Generally, the higher the current, the higher the magnetic field. Magnetic fields are measured in microteslas (μT).

Current can be likened to the flow of water when the nozzle is open.

Other Differences

One difference between electric and magnetic fields is that electric fields are very easily screened - by buildings, hedges, fences and trees. So inside a house there will be very little electric field from a power line outside. By contrast, magnetic fields pass readily through most buildings.
Another difference is that a mains appliance such as a radio or lamp does not have to be operating to produce an electric field - as long as it is plugged into a mains supply it will produce an electric field. However, it produces a magnetic field only when it is turned on and drawing a current.

EMF Units

Electric Fields	
Usually measured in volts per metre (V/m)	
Multiple used for large fields:	1 kilovolt per metre (kV/m) = 1,000 volts per metre
Magnetic Fields	
Usually measured in microteslas (μT)	
Multiple used for large fields:	1 millitesla = 1,000 microteslas
or small fields:	1 nanotesla = 0.001 microteslas
Other units sometimes used	1 milligauss = 0.1 microteslas

Instruments that measure field levels normally give an average value called the "root mean square".

Exposure

National Guidelines

The Government sets guidelines for exposure to EMFs in the UK on advice from the Health Protection Agency (HPA). In March 2004 the UK decided in principle to adopt the guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). These guidelines also form the basis of a European Union Recommendation on public exposure and a Directive on occupational exposure.

The ICNIRP 'reference levels' for the public are:

100 microteslas for magnetic fields

5000 volts per metre for electric fields

These are the levels above which more investigation is needed if this level of exposure is likely to occur; the permitted levels of exposure are somewhat higher, typically 360 microteslas and 9000 volts per metre but depending on the exact circumstances of the exposure. They apply where the time of exposure is significant. These guidelines are designed to ensure that EMFs do not interfere with nerves, but were set after examining all the evidence, including the evidence on cancer. The occupational limits are five times higher.

Reference levels are thresholds for performing detailed investigations of compliance. The permitted levels are somewhat higher.

It is the policy of the electricity industry to follow independent exposure guidelines and we are talking with Government about exactly where and how the guidelines will apply. All exposures in homes already comply with the ICNIRP guidelines. The electricity industry is committed to taking any further action, should it be necessary, as soon as Government decides the details of implementation.

Typical Field Levels in the UK

Natural Sources

The earth's magnetic field, which everybody is constantly exposed to, is around 50 microteslas in the UK. The earth's electric field is usually around a hundred volts per metre, but thunderstorms can make it rise to many thousands. Both these natural fields are 0 hertz or static fields. All the other values given in this section are for 50 hertz fields.

Within the Home

All electrical appliances produce magnetic fields which drop rapidly with distance.

Within our homes, all mains appliances produce fields. Appliances differ, but it is often the smaller, more compact appliances that produce the largest magnetic fields.

The field is greatest close to the surface of the appliance and drops rapidly with distance, falling away substantially over the first metre from the appliance. The table at the bottom of page 5 shows the range of magnetic field strengths close to the appliance. Electric fields can be a few hundred volts per metre close to appliances.

Typical Magnetic Field Levels from Some Common Mains Appliances in the Home

	Magnetic Field (microteslas)	
	Close to appliances	1 metre away
Vacuum cleaner	800	2
TV, Washing Machine, Microwave	50	0.2
Bedside Clock	50	0.02
Fridge	2	0.01

Outside the home

Overhead Lines

A line typically produces fields much less than the maximum it is capable of.

Outside our homes, all overhead power lines produce fields. The fields are usually greatest directly under the lines and fall rapidly with distance to the sides of the line. For small lines on wooden poles, the fields generally fall away over a few tens of metres. For larger lines on steel pylons, the distance is slightly greater. Fields vary greatly from line to line and over time, and a line typically produces fields much less than the maximum it is capable of.

Typical Ground-level UK Field Levels from Overhead Power Lines

		Magnetic Field (microteslas)	Electric Field (volts per metre)
The largest steel pylons (275 kV and 400 kV)	Maximum field (under line)	100	11,000
	Typical field (under line)	5 - 10	3,000 - 5,000
	Typical field (25 m to side)	1 - 2	200 - 500
	Typical field (100 m to side)	0.05 - 0.1	10 - 40
Smaller steel pylons and largest wooden poles (132 kV)	Maximum field (under line)	40	4,000
	Typical field (under line)	0.5 - 2	1,000 - 2,000
	Typical field (25 m to side)	0.05 - 0.2	100 - 200
	Typical field (100 m to side)	0.01 - 0.04	2 - 20
Wooden poles (11 kV and 33 kV)	Maximum field (under line)	7	700
	Typical field (under line)	0.2 - 0.5	200
	Typical field (25 m to side)	0.01 - 0.05	10 - 20
	Typical field (100 m to side)	<0.01	<1

Further information is available from:

www.emfs.info/

There is no restriction in the UK on EMF grounds on how close a house can be to an overhead line.

Underground Cables

High-voltage underground cables can produce higher magnetic fields directly above them than an overhead line would produce at ground level, because the physical distance from the underground cable is smaller. The field falls more rapidly with distance to the sides, and they produce no external electric field. Such cables are not normally located beneath buildings.

Substations

Small electricity distribution substations, typically one for every few hundred homes, generally produce up to 2 microteslas close to their perimeter fence or wall, and often no electric field at all. The fields fall rapidly with distance, and within 1 to 2 metres from a typical substation, the fields associated with it are usually indistinguishable from other fields present in homes. Larger electricity transmission substations do not produce very large fields themselves (generally less than a microtesla); the fields close by are mainly produced by power lines and cables entering them. There is no restriction on EMF grounds on how close houses can be to substations.

Average Magnetic Field Level

In the Home

In the vast majority of homes in the UK, the magnetic field, averaged over 24 hours, is between 0.01 and 0.2 microteslas, typically half the level in some other countries. In some homes it can be higher and in less than half a percent of UK homes the average level can be greater than 0.4 microteslas. Some of these homes are near power lines, but about half are not. Although no health risk has been established in these homes, there is particular interest in them because of the results of some scientific studies. This is discussed in more detail later in this guide (see page 8).

In the vast majority of homes in the UK, the magnetic field is between 0.01 and 0.2 microteslas.

It is actually easy to experience fields greater than 0.4 microteslas for short periods, close to an appliance or passing underneath a power line, but short exposures like these do not usually contribute much to the average field over a day.

Outside the Home

The occupations where exposure to fields has been investigated in greater detail tend to be those involving power workers. For instance, a typical worker in a UK power station experiences an average field of a few microteslas during working hours, and an electrician perhaps one microtesla. By contrast a typical office worker experiences about 0.2 microteslas. Fields in roads and public areas can be a microtesla above buried cables.

Potential Health Effects

Any suggestion of a risk to health must always be taken seriously. When considering issues of diseases and what causes them, it is important to look at what the scientific research reveals.

What Conditions have been Researched?

Most attention has focused on childhood cancer and leukaemia in particular. But other diseases including adult cancers, heart disease, Alzheimer's disease and depression have been examined, as has the incidence of suicide and miscarriage. "Electrosensitivity" involves conditions such as headaches, lethargy and depression.

There are three main types of research scientists do to try and find out whether EMFs cause disease.

Epidemiology

Epidemiology is the study of patterns of disease in populations. It searches for any statistical link or association between exposure to EMFs and disease in actual human populations. It was through such studies that concerns about EMFs were first raised in 1979.

The strength of epidemiology is that it looks directly at human populations. However, all it can ever do is observe statistical associations. It can never completely eliminate all the many other factors that determine whether people develop diseases or not, and so it can never prove whether a particular disease is caused by EMFs or not.

Around 20 epidemiological studies have been performed looking at a possible link between childhood leukaemia and EMFs.

Around 20 epidemiological studies have now been performed looking just at a possible link between childhood leukaemia and EMFs. Numerous other studies have looked at other diseases. Some of those studies found no association with magnetic fields, but some have found associations, and consequently research continues until a clearer picture can be achieved.

With electric fields, the position is clearer: there is very little evidence suggesting they are a cause of childhood cancer.
All these studies have been reviewed by the HPA and its conclusions are considered later in this guide (see page 10).

Theoretical

Theoretical research looks for a plausible mechanism that can demonstrate how the fields could interact with living systems. Many theories have been put forward over the years, but no such mechanism has been established that would operate at the levels of field found in homes or near power lines, and this casts doubt on the existence of health effects.

Biological

An important test of any proposed health risk is biological research: laboratory research actually to observe the effects of EMFs on cells and tissue.

There have been many hundreds of these studies reported, and scientists examine them for robust results, which can be successfully repeated in different laboratories.

In over 20 years of research there have been no such reproducible results. The evidence from the laboratory is that low level EMFs of the type experienced by the public do not cause the diseases that have been claimed.

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Some Recent Important Research Results

The two biggest epidemiological studies of childhood cancer and EMFs so far both come from the UK.

The United Kingdom Childhood Cancer Study (UKCCS)

The UKCCS was conducted during the 1990s. It looked at a number of suggested causes of childhood cancer including EMFs. Its particularly large study population -over 2000 cases of cancer in total, every case occurring in the UK over roughly a four-year period -made it very powerful.

In December 1999, the UKCCS published its first report, on exposure to magnetic fields, and concluded:

“This study provides no evidence that exposure to magnetic fields associated with the electricity supply in the UK increases the risk for childhood leukaemia, cancers of the nervous system, or any other childhood cancer.”

Subsequent UKCCS papers in 2000 and 2002 looked at children living close to power lines and at electric fields, in both cases reporting finding “no evidence” or “no support”.

The Childhood Cancer Research Group (CCRG)

This 2005 study, also known as the “Draper” study, looked at 33,000 cases of childhood cancer from 1962 to 1995 and the distance of their address at birth from the nearest 275 kV and 400 kV power line. It found an association between childhood leukaemia and these power lines (1.7-fold increase close to the lines, less further away).

But this association extended too far (600 m) from the lines to be caused by magnetic fields. There is no simple explanation for this finding, and the paper concludes:

“We have no satisfactory explanation for our results in terms of causation by magnetic fields or association with other factors.”

‘Pooled’ Analysis

In 2000, an international group, led by Professor Anders Ahlbom from Sweden, took all the separate better-quality epidemiological studies of childhood leukaemia and magnetic fields and pooled the results, so that they could perform one single re-analysis of all the available data. They found that, statistically, there was no significant evidence of any increased risk at the levels of magnetic field to which the overwhelming majority of children are exposed.

The study did, however, find that in the category of homes with a field, averaged over 24 hours, of greater than 0.4 microteslas (which applies to fewer than half a percent of children in the UK), there is a statistical suggestion of a two-fold increased risk. Some of these homes are near power lines, but many are not.

A statistical finding like this may or may not reflect a real cause-and-effect relationship. It is unlikely to be due to chance, but it could be an artefact of the studies.

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The authors themselves concluded: **“The explanation for the elevated risk is unknown, but selection bias may have accounted for some of the increase.”**

Although this study is inconclusive, it is seen by some as a key piece of evidence.

Conclusion

The UKCCS did not support EMFs causing cancer, but the pooled analysis did suggest an increased risk. The CCRG study reinforces a link between power lines and leukaemia, but suggests it may not be caused by EMFs. Evidence from other research such as laboratory studies argues against any link.

Looking at the totality of the evidence, scientists recognise the possibility of a risk for the relatively few children who receive the highest exposure to magnetic fields, but it is no more than a possibility.

The Words ‘Risk’ and ‘Possible’

Nothing can ever be said to be ‘100% safe’ or ‘risk free’. Everything we do from the moment we get up to when we go to sleep has a ‘risk’ attached to it. Most of the risks we encounter in our day-to-day lives or we hear talked about are established or proven risks, where scientific evidence has reached firm conclusions. This enables us to decide -either as individuals or together as a society -on what actions to take in response to the risks.

Any suggestion of a possible health risk is always taken seriously by the electricity industry. For this reason, the industry will continue to support high quality research.

With EMFs and risk the situation is different: no risk has been proven. Instead, EMFs are sometimes described as a ‘possible’ cause of cancer or a ‘possible carcinogen’. The word ‘possible’ is used about all sorts of things in our lives. It does not mean that exposure to EMFs actually does pose a risk. It simply means that there is some evidence and scientists have not been able to rule out the possibility of a risk, which on the basis of present evidence would be small.

However, any suggestion of a possible health risk is always taken seriously by the electricity industry. For this reason, the industry will continue to support high quality research to help to gain a clearer picture of EMFs and to move closer to a final answer.

Corona Ions and Electric Fields

Scientists at Bristol University in the UK have suggested an alternative mechanism for health effects, involving tiny airborne “corona ions”, produced by high-voltage power lines, and their interaction with existing airborne pollutants. These physical processes do undoubtedly happen, but in 2004 the HPA’s forerunner concluded:

“...it seems unlikely that corona ions would have more than a small effect on the long-term health risks associated with particulate air pollutants, even in the individuals who are most affected.”

Microshocks

The electric field beneath a power line charges up objects, and sometimes, if you touch a metal object, you can receive a small one-off “microshock”, similar to the shock you sometimes get after walking on a nylon carpet. This can be disconcerting but has no known long-term effect and is not regarded as harmful.

The National and International View

In the UK, it is to the HPA and their forerunner the National Radiological Protection Board (NRPB) that both Government and industry look for advice. In March 2004, the NRPB published a comprehensive review of the science on EMFs. For the key issue of childhood leukaemia, they talk about the difficulties with some of the studies and say: **"The epidemiological evidence is currently not strong enough to justify a firm conclusion..."**, but also: **"Nevertheless, the possibility remains that intense and prolonged exposures to magnetic fields can increase the risk of leukaemia in children..."**

Another key conclusion is: **"There is little evidence to suggest...that raised cancer risks of other types, in children and adults, might arise as a result of exposure to ELF [extremely low frequency] magnetic fields...The findings from studies of health outcomes other than cancer have generally been inconsistent or difficult to interpret."**

The results of epidemiological studies cannot be used as a basis for quantitative restrictions on exposure to EMFs.

They then note: **"The results of epidemiological studies...cannot be used as a basis for the derivation of quantitative restrictions on exposure to EMFs."**

These views echo the international consensus. For example, in June 2001, the International Agency for Research on Cancer, IARC, which is an agency of the World Health Organization, published an authoritative opinion on the carcinogenicity of EMFs. IARC classified extremely low frequency magnetic fields as 'possibly' a cause of cancer, on the basis of 'inadequate' epidemiological evidence for most types of cancer and 'inadequate' evidence in animals, but 'limited' epidemiological evidence for childhood leukaemia. For electric fields, IARC said all the evidence was 'inadequate'. In 2005, WHO confirmed this classification, but also looked at other effects on health, and said the evidence for any of these being produced by EMFs was **"much weaker".**

Some scientists hold other views, and sometimes reports are published saying the evidence is stronger (for example, a 2002 report from California and the 2007 Bioinitiative report). But such assessments are clearly out of line with the international consensus and with authoritative bodies.

The UK Electricity Industry Policy

Health

The electricity industry has dedicated EMF resources to assist the public.

The UK electricity industry takes any suggestion of a risk to health extremely seriously. The industry believes that the final decision about what constitutes a safe level of exposure should be made by an independent body. It is committed to follow the guidance given by the Government, advised by the HPA, on safe levels of exposure and carries out all its operations within the relevant exposure levels.

Because the electricity industry takes public concern seriously, it has dedicated EMF resources to assist the public and to provide further information, including, if appropriate, home visits and measurement of fields.

Research

It is a condition of all the research supported by the industry that the results should be published openly.

The electricity industry is committed to supporting high-quality research to help get closer to a final answer on the EMF issue. For example, the UK Childhood Cancer Study received over £4 million from the industry to enable it to look at EMFs in their study, though the conduct of the study was rigorously independent of the industry. Similarly, one of the electricity companies, National Grid, funds an independent Research Trust to support the very best quality biological research.

In addition, the industry has supported and continues to support numerous other studies, and its own staff carry out research into aspects of exposure to EMFs. National Grid provided the data on power lines that made the CCRG study possible. It is a condition of all the research supported by the industry that the results should be published openly in reputable peer-reviewed, scientific journals.

Amenity

All power lines comply with the Government's requirements. However, it is worth noting that normal good practice in planning new high-voltage lines ensures that they are kept as far away from existing homes as possible, simply on grounds of amenity. Subsequent new housebuilding, however, may bring homes into closer proximity to these lines.

Power lines and property

The UK Government policy is that there are no restrictions on EMF grounds on building homes close to power lines. Clearly the statutory high-voltage safety clearance distances must be followed, but the only EMF requirement is compliance with the exposure guidelines, which all power lines in the UK meet.

This policy has been scrutinised and reviewed over the last few years through a process called SAGE, the Stakeholder Advisory Group on ELF EMFs. SAGE was created in 2004 to provide a forum in which all stakeholders – citizen groups alongside industry, Government and professional bodies – could discuss possible precautionary measures and make recommendations. SAGE published its First Interim Assessment in 2007, containing recommendations on power lines, house wiring and appliances, and Government formally responded in October 2009.

That Government response adopts a measure recommended by SAGE called “optimum phasing” which applies to the design of some power lines of 132 kV and above and can result in lower fields, and the electricity industry has already volunteered to implement this. It also agrees with a proposal for more information to be provided to the public. It notes that some of the recommendations on house wiring are happening anyway for other reasons. But Government say clearly that it will not be introducing “corridors” along power lines where building would be restricted, because this would be disproportionate to the scientific evidence. It also says that this is a matter for central Government policy, not local decision making.

The Electricity Industry View

The electricity industry considers that the question of possible measures to reduce fields should be resolved in the best interests of society as whole, and that a forum like SAGE where all the different views and opinions were represented and discussed sensibly is greatly preferable to the alternative of confrontation and argument. We therefore welcome the clarity that the SAGE process and the Government response to it has brought.

We are committed to building and operating our systems in compliance with Government policy. They already comply with the exposure guidelines. Where there are relatively easy and low-cost ways of reducing fields, it makes sense to adopt these. But it is in the interests of society as a whole that any measures are proportionate and that they balance risk and cost to society, and that is the reason why Government has decided not to introduce “corridors” in the UK.

The electricity industry was instrumental in setting up SAGE and we have supported it throughout.

Further Information

For further information you can contact

• The Energy Networks Association website:
www.energynetworks.org

• National Grid information site on EMFs:
www.emfs.info

• The EMF Unit Public Information Line
can be contacted on **0845 702 3270**

• Your local electricity distribution company

• The HPA website: **www.hpa.org.uk/radiation**
or telephone them on **01235 831 600**

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