WHO'S AFRAID OF POWER LINES?

Exposure to electromagnetic fields often raise concerns about possible health consequences. These concerns tend to focus on high-frequency electromagnetic fields, such as those used for mobile communication, or low frequency magnetic fields, such as those occurring during electricity transmission in power lines. A literature study on extremely low-frequency magnetic fields put these fears into perspective: according to this review of current research, the fields cause no significant danger to the health of the population. However, the authors suggest for selected areas to collect more and better data in order to assess more robustly potential risks.

When the toaster is plugged in, there is an electrical voltage in the appliance and as a result, an electric field. If the toaster is turned on, an electric current flows and this then generates a magnetic field. Electromagnetic fields are an indispensable part of our modern everyday life: they make it possible to wirelessly transmit electrical energy in inductive charging stations; or they transfer information—for instance a telephone conversation from the mobile phone to the nearest base station antenna, a radio program from the Uetliberg Antenna to

According to current research, power lines pose no significant public health threat to the population, a literature study by the Forschungsstiftung Strom and Mobilkommunikation shows. Photo: Swissgrid

A technical report about the results of a research project in the field of electricity, which is financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine Bulletin SEV/VSE (issue February 2018).

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the receiver in the old town of Zurich, or a website content from the router via the WLAN to the PC.

The latter applications use high frequency (30 kHz to 300 GHz) electromagnetic fields. In the power supply, by contrast, low-frequency electromagnetic fields are used (<1 kHz). In Europe, the power supply works with 50 Hz, in the USA with 60 Hz. These extremely low-frequency (ELF) electric and magnetic fields are pervasive in everyday life: they are produced by the transformer in the clock radio, by conventional coil chargers, by the heat coil of the coffee machine, but also by the vacuum cleaner or the drill machine and by all electric wires installed in apartment walls. In most cases, and in normal use distances, these fields are rather weak. ELF fields also accompany us when we travel: they come from overhead electric cables that power trains (trams and buses often use static fields). Anyone who is directly under a high-voltage cable is exposed to comparatively strong electromagnetic fields. With distance, the field strength decreases quickly, so that at distances of a few tens of meters the fields are mostly comparable with those that occur in households.

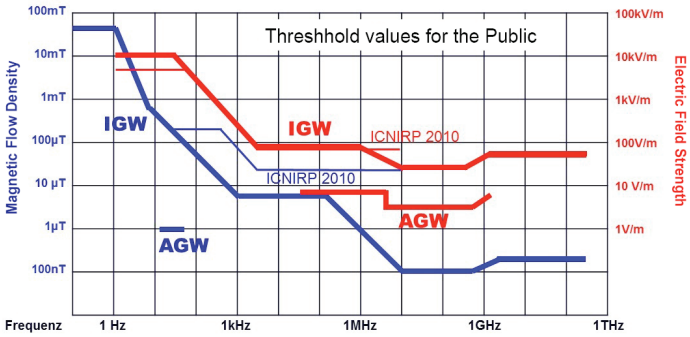
No Large Risks Discovered

A literature study commissioned by the Swiss Federal Office of Energy has now tried to clarify the question whether extremely low-frequency fields that are typical of our power supply, are associated with health risks. High-frequency fields such as those used by mobile communication were not subject of the study. The work focused on the effects of low-frequency magnetic fields. Low-frequency electric fields as known in everyday life are not considered a threat to health. The study was carried out by the Research Foundation for Electricity and Mobile Communications (Forschungsstiftung Strom und Mobilkommunikation/FSM), a foundation located at ETH Zurich, and financially supported by industry (including Swisscom and Swissgrid), with both non-governmetal and governmental supporters including the Swiss Federal Office of Public Health, the Swiss Federal Office for the Environment and the Swiss Federal Office of Energy. In its study, the FSM evaluated the scientific literature on extremely low-frequency magnetic fields (in particular 50/60 Hz and 16.7 Hz / traction current) that was published between 2010 and March 2017. The focus was on health studies. Almost all of the studies considered were "peer reviewed", so their quality was ensured by scientists working in the field.

In the study summary the authors state: "Collectively, the literature analysis shows that science has not identified any

FSM Director and lead author of the literature study on low frequency magnetic fields: Dr. Gregor Dürrenberger. Photo: Landbote / Johanna Bossart

major health risks in recent years." Leukemia disorders in children have long been at the center of the discussion about possible risks of low-frequency magnetic fields. Recent studies examined in particuar the risk for children exposed to relatively strong magnetic fields. This refers to flux densities greater than 0.4 micro-Tesla that, for example, occur below and near power lines or in buildings with transformer stations. Recent studies confirm what the cancer research agency IARC oft the World Health Organization (WHO) had already identified in 2001: low frequency magnetic fields are "possibly carcinogenic." Possibly carcinogenic means that although many available studies indicate an increased risk, the causal link is not confirmed scientifically (see table p.3). To put the risk in perspective: if it is real, 1 to 2 leukemia ca-



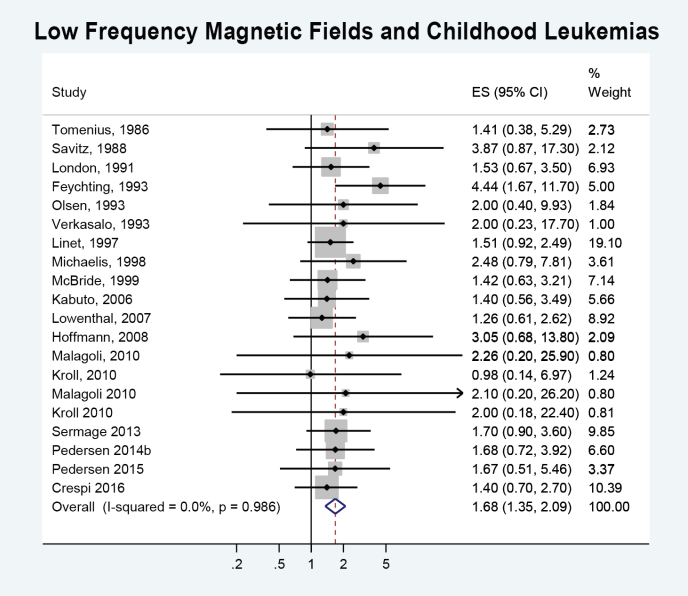
Rules of the Ordinance on Non-Ionizing Radiation Protection (NISV) limit the electromagnetic fields of infrastructure facilities, such as energy supply. The abbreviations refer to the following: IGW = emission limit value of the NISV; AGW = precautionary limit value of the NISV; ICNIRP 2010 = Recommendation of the International Commission for the Protection against Non-Ionizing Radiation. In addition, there are limits imposed on exposure to electromagnetic fields at the workplace issued by SUVA. Source: FSM

ses in Swiss children would be attributable to magnetic fields every year, according to the scientists.

No Known Mechanism of Action

"There seems to be a relationship between magnetic fields above 0.4 micro-Tesla and leukemia, but we do not yet understand it," says FSM Director and co-author Dr. Gregor Dürrenberger. So far, it is particularly unclear whether the relationship is causal—in other words that leukemia is biophysically caused by magnetic fields. According to Dürrenberger, there is no known mechanism of how a magnetic field might raise leukemia. The Zurich-based researcher advocates more in-depth research: "New approaches are needed: cohort studies, for example, that include vulnerable populations (e.g., children with Down's syndrome) or that include a high proportion of highly exposed children (e.g. children in buildings with a transformer). Also of interest are gene-environment interaction studies, as these could indicate possible biological mechanisms of action."

The FSM study has also evaluated the available study results for other possible diseases. According to the current state of knowledge, exposure to ELF magnetic fields do not increase the risk of developing brain tumors nor breast cancer. The results of research on leukemias and lymphomas (lymph node



Overview of 20 cancer studies on the effects of extremely low-frequency magnetic fields from the past 30 years: The risk estimator (points) of almost all studies lies to the right of the zero risk line (vertical line at 1), suggesting that there is a correlation between strong low-frequency magnetic fields and childhood leukemia. However, in 19 of the 20 studies, the confidence interval (horizontal line) crosses the zero-risk line, which means that this correlation is not significant (statistically confirmed). Table: Final report SFOE study 'EMF of electricity technologies.'

	Cell Studies	Animal Studies	Human Studies		
			Biology	Acute Health Effects	Chronic Health Effects
Cancer					
Tumors in head area					
Tumors in children					
Other tumors					
Neurodegeneration neuronal diseases					
Parkinson's, MS					
Alzheimer, Demenz, ALS					
Reproduction					
Development					
Cardiovascular/blood system					
EEG					
Cognition					
Children					
Sleep					
Children					
Electrosensitivity					
Noceboeffect					
Children					
Hormonal					
Melatonin					
Stress proteins/Gene-expression					
Blood-brain barrier					
Behavior-general					
Children and young adults					
Mechanism of Action					
Genetic damage					
Free radicals					
Gene-expression					
Cell function/membrane					

The table summarizes the current state of research on the effects of low-frequency magnetic fields: Red: effect sufficiently proven. Orange: effect proven with limitations. Yellow: Effect inadequately demonstrated (study data contradictory, studies not meaningful, too few studies for serious conclusion). Green: indicates the absence of a causal effect. Table: G. Dürrenberger

Frequency greater than	Wavelength smaller than	Wave Type/Band		Bandwidth approximate	Frequency Category	Physical Effect	Example Applications		Spreading Properties
300 PHz	1 nm	Gamma Rays			Ionizing Radiation	Breaking of Chemical Bonds	Nuclear Physics		Skywaves; penetration into the body
3 PHz	100 nm	X-Rays					X-Ray Machines		
0.75 PHz	400 nm	UV-Radiation			Optical Radiation		Sunlamps		
300 THz	1 µm	Light					Lamps		Skywaves; visibility
30 THz	10 µm	Infrared					Heating		
3 THz	100 µm								
300 GHz	1 mm						*Nothing yet*		
30 GHz	1 cm	EHF	Microwaves	300 GHz	Highfrequency Radiation	Heating of Tissues	Radar (diverse frequencies)		Skywaves; visibility
3 GHz	10 cm	SHF		30 GHz			SAT-Comm. (11-13 GHz) Radar (diverse frequencies) Radio relay systems (div. freq.)		Skywaves; visibility 5 Ghz is the limit of building penetration
300 MHz	1 m	UHF		3 GHz			Microwave Oven (2455 MHz) GPS (1575 MHz) Mobile Comm. (900, 1800 MHz)		Skywaves; +/- visibility, reflection up to approx. 30 km
30 MHz	10 m	UKW (VHF)	Radiowaves	300 MHz			TV (40-900 MHz) Radio (87-108 MHz)		Skywaves; reflection possible; to permeate the Ionosphere up to 100 km
3 MHz	100m	KW (HF)		30 MHz			Radio	(2.3-26 MHz)	Ground-, Skywaves; reflection on water, Ionosphere, up to 10000 km
300 KHz	1 km	MW (MF)		3 MHz				(530-1600 KHz)	Groundwaves Up to approx. 1000 km
30 KHz	10 km	LW (LF)		300 KHz				(150-280 KHz)	Groundwaves Up to approx. 5000 km
3 KHz	100 km	VLF		30 KHz			Underwater Communication Displays		Groundwaves; penetration into water, reflection in the Ionosphere
300 Hz	1000 km	ELF		300 Hz	Lowfrequency Radiation	Stimulation of Nerves	Telephone		No usable radiation
30 Hz	10'000 km						Electric power supply Household appliances Railroad		

The Research Foundation for Electricity and Mobile Communications (FSM) has investigated low-frequency magnetic fields (green) in a literature study. High-frequency (orange), optical (yellow) and ionizing (blue) radiation were not subject to the study. All types of radiation have physical effects, including on the body: high-frequency and optical radiation (especially infrared) causes heating of body tissue. For radio applications, this warming is extremely weak and causes no health problems. Also, the excitation / stimulation of nerves by low-frequency fields is usually below the perceptual threshold. For example, only magnetic fields that greatly exceed the limits can cause muscle contractions or visual dysfunction. Legal limits and SUVA regulations ensure that the various types of radiation do not cause harm to humans. Last but not least, this also applies to high-energy radiation such as X-rays, which have great medical benefits, but at high intensity can break-up of chemical bonds and thus damage tissues. Table: FSM

tumors) in adults are inconsistent. In Parkinson's disease and Multiple Sclerosis, an increased risk is unlikely, while in dementia diseases such as ALS (Amyotrophic Lateral Sclerosis) and Alzheimer, the studies tend to show a slightly increased risk for heavily exposed individuals (occupational exposures).

People Senstive to Electromagnetic Fields

The FSM study also evaluated studies on electromagnetic hypersensitivity. This refers to the phenomenon of people attributing insomnia, headache, lack of concentration, rheumatism, itching and other symptoms to the presence of electromagnetic fields. The findings of the FSM study: "There may be a small group of people who perceive certain electromagnetic fields stronger physiologically than other people. Overall, the present exposure studies show that there is no relationship between well-being and the presence or absence of electromagnetic fields. On the other hand, the symptom level is almost always linked to the belief that one is exposed to a field, a clear indication of the effectiveness of nocebo effects. It is thus likely that electrohypersensitivity has a mental, not a physical, cause."

Gregor Dürrenberger has summarized the previous scientific assessments of the health effects of ELF magnetic fields in a table (see table). It shows that science can not yet provide conclusive risk assessment for a number of areas. Nevertheless, Gregor Dürrenberger has no doubt that science is the only suitable tool for the objective assessment of potential health risks associated with electricity supply: "Scientific studies are the only source to reliably assess health risks, guessing does not help us in this area" says the ETH scientist.

- The **final report** on the research project 'Electromagnetic Fields of Power Technologies' can be found at: https://www.aramis.admin.ch/Texte/?ProjectID=35901.
- **Further information** on the project is available from Dr. Gregor Dürrenberger (gregor@emf.ethz.ch), Managing Director of Forschungsstiftung Strom und Mobilkommunikation.
- Further **technical papers** on research, pilot, demonstration and flagship projects in the field of electricity technologies can be found at www.bfe.admin.ch/CT/strom.

UNDERGROUND POWER LINES NOT NECESSARILY HELPFUL

Today, when construction and renewal of high-voltage power lines are discussed, many favour underground installations. Underground cables, however, have also limitations. In terms of landscape conservation, broad clearance corridors are necessary in forests. With respect to radiation, the magnetic field strengths are really high in the immediate vicinity of the cables (at a greater distance, they are smaller), Gregor Dürrenberger of the FSM remarks. Soil does not shield magnetic fields, so a person standing directly over an underground cable can by more exposed compared to a person standing below overhead power lines, because the distance to the buried cables is shorter than the distance to overhead lines. Underground cables are placed closer to each other, which for physical reasons, causes the magnetic field to concentrate in a smaller space.

By contrast, a reduction of the magnetic field could be achieved when a given power is transported at a higher voltage, for example 380 kV instead of 240 kV. If one transmits the same power with a higher voltage, the current flow decreases - and thus also the associated magnetic field generated by this current. BV

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