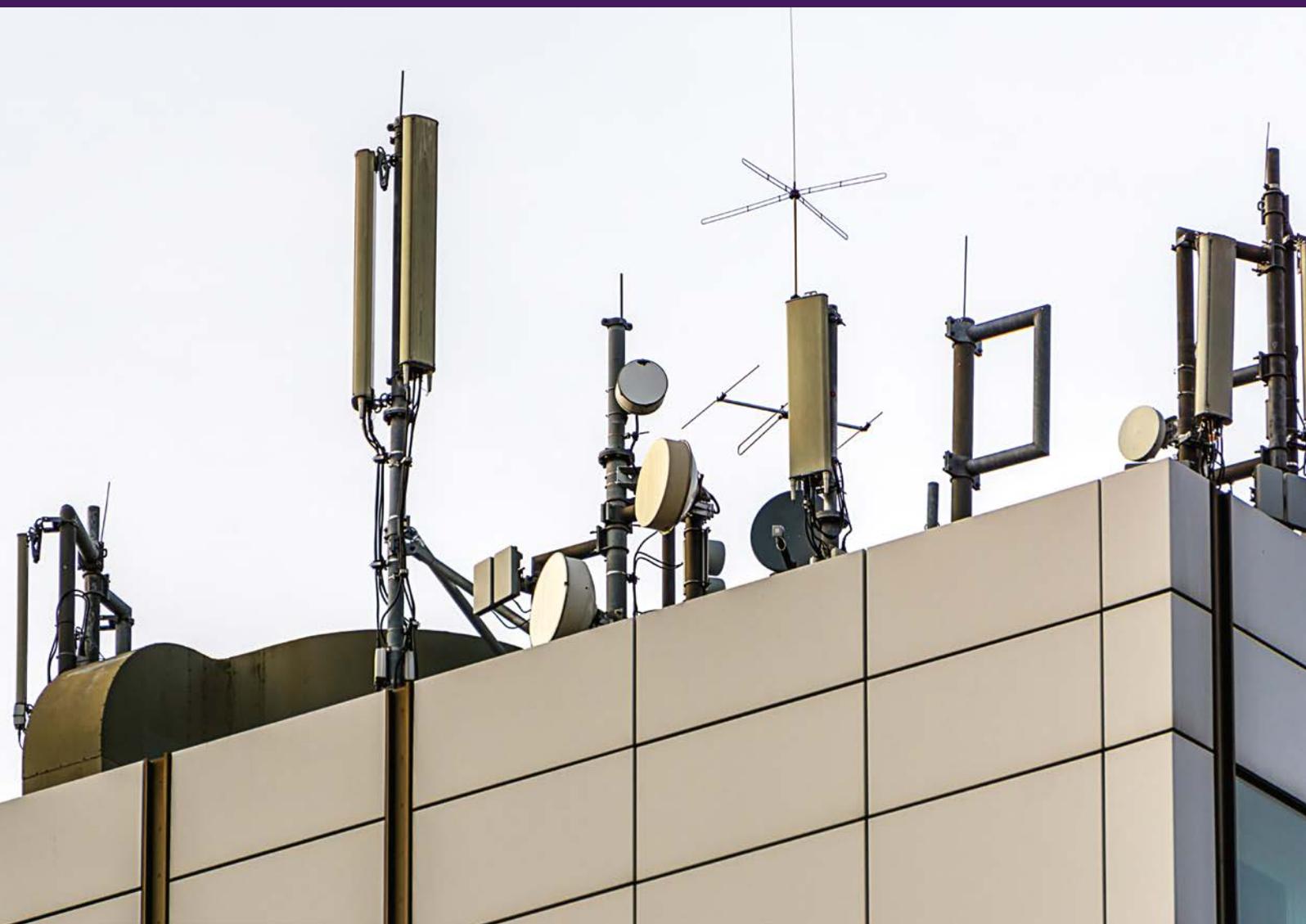




National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Comparison of *international* policies on *electromagnetic fields* (power frequency and radiofrequency fields)



Comparison of international policies on electromagnetic fields (power frequency and radiofrequency fields)

This document is an update of an earlier overview from May 2011 (RIVM 118/2011). It was prepared as part of a research project commissioned by the Ministry of Infrastructure and Water Management and the Ministry of Social Affairs and Employment of the Netherlands. The information that forms the basis for this summary was obtained from searches of governmental and scientific websites, scientific publications, policy summaries by other organisations and personal contacts with experts in the countries in question. The information was last updated in the period from January to July 2017¹.

Introduction

Time-varying electric, magnetic and electromagnetic fields (EMF) are generated by moving electric charges and by variable electric fields such as those generated near a conductor for alternating current. Power frequency EMF are generated in the production, transport, distribution and use of electricity. The frequency of alternating current and the resulting EMF is 50 hertz in Africa, most of Asia, Australia, Europe and part of South America and 60 hertz in the remainder of America, the Philippines, Korea, Saudi-Arabia and part of Japan. Radiofrequency EMF are generated, among others, by mobile telecommunication systems, broadcasting transmitters, radar installations, microwave ovens and dryers, plastic welders, certain medical applications and equipment for electronic article surveillance and identification.

In 1999, the Council of the European Union (EU) published a Recommendation (1999/519/EC, further called 'EU recommendation') on the limitation of exposure of the general public to EMF (0 hertz to 300 gigahertz). It contains basic restrictions for the induced electric fields and currents and the absorbed power in the body and reference levels for the strength of EMF outside the body (for values at selected frequencies, see **Table 1**). The limits in the EU

recommendation are derived from the 1998 guidelines for limiting exposure to EMF by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP has issued new guidelines for EMF with frequencies between 1 hertz and 100 kilohertz in 2010, and for frequencies between 0 and 1 hertz in 2014, but these have not yet led to changes in the EU recommendation.

In 2013, the European Parliament and the Council of the EU issued a directive (2013/35/EU, further called 'EU directive') on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (EMF). It contains exposure limit values for the induced electric fields and the absorbed power in the body and action levels for the strength of EMF outside the body (for values at selected frequencies, see **Table 2**). The limits for static and low frequency fields in the EU directive are derived from the 2009 and 2010 ICNIRP guidelines for limiting exposure to static and low frequency time-varying EMF. The limits for radiofrequency fields are derived from the 1998 ICNIRP guidelines. ICNIRP has reconfirmed the validity of its 1998 guidelines for EMF with frequencies between 100 kilohertz and 300 gigahertz in a 2009 statement. For the sake of consistency, the terminology of the EU recommendation and EU directive is also used for equivalent public and occupational exposure limits in national legislation in the present summary, regardless of whether these are derived directly from ICNIRP or from other sources.

The European Parliament and Council of the EU have also issued directives on the marketing of low voltage electrical equipment (2014/35/EU) and radio equipment (2014/53/EU), which require that such equipment does not endanger the health or safety of persons. The European Committee for Electrotechnical Standardisation (CENELEC), in liaison with the European Telecommunications Standards Institute (ETSI), has developed harmonised standards for measurement and calculation of EMF exposure which can be used to demonstrate that this requirement is met.

¹ **Disclaimer:** The author has taken care to obtain correct and up-to-date information from relevant websites, policy documents and experts in the countries in question. However, no rights can be deduced from any of the information in this document. For further information and corrections, please contact Dr. R. Stam, National Institute for Public Health and the Environment, the Netherlands. E-mail: rienne.stam@rivm.nl

Apart from ICNIRP, influential guidelines on the protection against risks of EMF have also been published by the Institute of Electrical and Electronics Engineers (IEEE), for both exposure of the general public and controlled environments (occupational exposure). For power frequency fields, the IEEE basic restrictions for induced electric fields are similar to those of ICNIRP and EU for exposure of the head (brain) but less strict than ICNIRP for exposure of the rest of the body. For radiofrequency fields, IEEE basic restrictions are the same as those of ICNIRP and EU. The reference levels of IEEE are less strict than those of ICNIRP and EU (for radiofrequency fields only at some frequencies). Differences in the limits between different guidelines are mainly caused by differences in the dosimetric models of the human body and in the use of safety factors. The limits advised by IEEE are used in national EMF legislation of some countries outside the EU and referred to in a safety standard of the North Atlantic Treaty Organization (NATO).

Exposure of the general public, power frequency fields

European Union

Because the EU recommendation is not legally binding, EMF policy in member states can be divided into three different approaches. Details on limits at selected frequencies per member state can be found in **Table 1** and a visual overview in **Figure 1**. In the **first group** of member states the EU recommendation has been transposed in binding national legislation or national policy. This means that the basic restrictions and reference levels must be applied. EU member states in this group are the *Czech Republic, Estonia, France, Greece, Hungary, Ireland, Luxemburg, Portugal and Romania*. In the *Czech Republic*, the reference levels differ from the EU recommendation, but the basic restrictions are the same. In *France* the limits only apply to new or modified installations. In *Germany* and *Slovakia* the reference levels in the EU recommendation are applied as *de facto* exposure limits, without reference to basic restrictions.

In the **second group** of member states, the national limits based on the EU recommendation or ICNIRP are not binding, there are more lenient limits or there is no regulation. However, it may be that the authorities or grid companies apply the limits in the EU recommendation in practice. EU member states in this group are *Austria, Cyprus, Denmark, Finland, Latvia, Malta, the Netherlands, Spain, Sweden and the United Kingdom*.

Whether or not they have legally binding limits on the strength of power frequency fields, in some of the EU member states in the first and second group a precautionary policy has been advised by the government or voluntarily agreed to by the electricity supply sector to limit the exposure of members of the general population to power frequency magnetic fields. Alternatively, the legislation contains an obligation to minimise fields as far as this can be done with reasonable cost and with reasonable consequences. The motivation is either the epidemiological evidence for a possibly increased risk of childhood leukaemia in children who live near overhead power lines, or a more general argument to keep fields as low as reasonably possible in the light of scientific uncertainty. These precautionary policies in addition to formal legislation are as follows:

First group

France: A ministerial recommendation advises the Prefectures to avoid as far as possible the creation of new hospitals, maternity wards and childcare facilities near power lines, cables, transformers and bus bars where children are exposed to a magnetic field stronger than 1 microtesla. For new or modified electricity infrastructure, the grid operator usually tries to avoid as much as possible the creation of new electricity infrastructure near such locations when planning a new grid development. The grid operator has the legal obligation to monitor the strength of EMF near power lines in urbanised areas. Citizens can also request information about the strength of EMF from local power lines via their mayor.

Germany: National legislation requires that all possibilities to minimise EMF should be exhausted in accordance with the technical state of the art when creating or substantially modifying direct current and alternating current facilities with voltages greater than 1 kilovolt. High-voltage power lines for alternating current on a newly planned route may not pass over buildings meant for the long-term stay of people. The obligation to minimise EMF only applies to locations with homes, hospitals, schools, childcare facilities, playgrounds or any other location not exclusively meant for the temporary stay of people. Minimisation measures need to be proportional with regard to cost, functionality, or negative effects on the environment, well-being and occupational safety.

Luxemburg: There is a ministerial recommendation not to create any new living spaces in the immediate vicinity of overhead power lines (within 20 metres for 65 kilovolt lines and 30 metres for 100 to 220 kilovolt lines).

Second group

Austria: Although precautionary limits are not formally advised, the panel of experts appointed by the relevant authority for new electricity lines requiring environmental impact assessment usually require compliance with a maximum magnetic flux density of 1 microtesla (1% of the reference level in the EU recommendation), derived from Swiss legislation.

Denmark: The Danish Health Authority (Sundhedsstyrelsen) recommended in 1993 not to build new homes or children's institutions close to power lines or new power lines close to homes or children's institutions. The exact distance was left to pragmatic considerations. The Danish electricity sector has published guidelines for situations where measures at reasonable cost to reduce the magnetic field must be investigated. Like the Danish Health Authority's advice, the guidelines apply only to new developments.

Finland: The Radiation safety authority (STUK) recommends avoiding the construction of permanent residences in areas where the magnetic flux density continuously exceeds the level of approximately 0.4 microtesla.

Netherlands: A ministerial recommendation advises local authorities and grid companies to avoid as far as reasonably possible creating new situations with long-term stay of children in areas around overhead high-voltage power lines with an annually averaged magnetic flux density greater than 0.4 microtesla. The advice applies when making spatial plans and determining the trajectory of overhead high-voltage power lines, or when changing existing plans or existing overhead high-voltage power lines. For existing situations, the reference level in the EU recommendation should apply.

United Kingdom: In response to the conclusions of a national stakeholders' dialogue, the government noted that ICNIRP exposure guidelines in place in the United Kingdom remain appropriate. It also supports the implementation of low-cost options such as optimal phasing to reduce the magnetic field of overhead power lines, but considers additional exposure reduction by creating exclusion zones between homes and power lines to be disproportionate in the light of the evidence on the potential health risks. The government also supported exploring the reinforcement of best practice for wiring of distribution circuits and providing consistent, helpful and proportionate public health messages to raise awareness.

In the **third group** of member states, there are stricter basic restrictions and/or reference levels, based on the precautionary principle or due to public pressure. These stricter reference levels are often applied as a *de facto* exposure limit that may not be exceeded. Since there is a great diversity in particular rules and limits, a summary is given per member state:

Belgium: In Belgium, the limitation of EMF exposure of the general population is a matter for the three devolved regions. In Flanders, a ministerial recommendation for the planning of new power lines states that passing over schools and childcare centres should be avoided and

passing over homes kept to a minimum. New schools and childcare centres should not be placed in the magnetic field zone with year-averaged exposure greater than 0.4 microtesla (0.4% of the reference level in de EU recommendation). In addition, an indoor environment decree requires those responsible for building or managing homes and public buildings to keep exposure to power frequency magnetic fields below 10 microtesla (10% of the reference level in de EU recommendation) and advises them to strive for a 'quality aim' of 0.2 microtesla (0.2% of the reference level in de EU recommendation). In the Brussels region, a ministerial instruction for environmental permits requires that the magnetic field in places near newly installed transformers where children under 15 may stay is kept below a 24-hour average of 0.4 microtesla. Wallonia does not have a precautionary policy for power frequency magnetic fields, but applies the limits in the EU recommendation to transformers.

Bulgaria: Minimal distances between homes and power lines or substations are in force depending on voltage. There are no other limits for exposure of the general public to power frequency EMF except for limits on emission by video screens. At a distance of 50 centimetres from video screens, the limit is 0.5% of the reference level in the EU recommendation for electric field strength and 0.25% for magnetic flux density.

Croatia: For public spaces in general, limits for the electric and magnetic field identical to the reference levels in the EU recommendation may not be exceeded. For 'sensitive areas' (homes, offices, schools, playgrounds, kindergartens, maternity wards, hospitals, homes for the elderly and disabled and tourist accommodations), the limits for the electric and magnetic field are 40% of the reference levels in the EU recommendation.

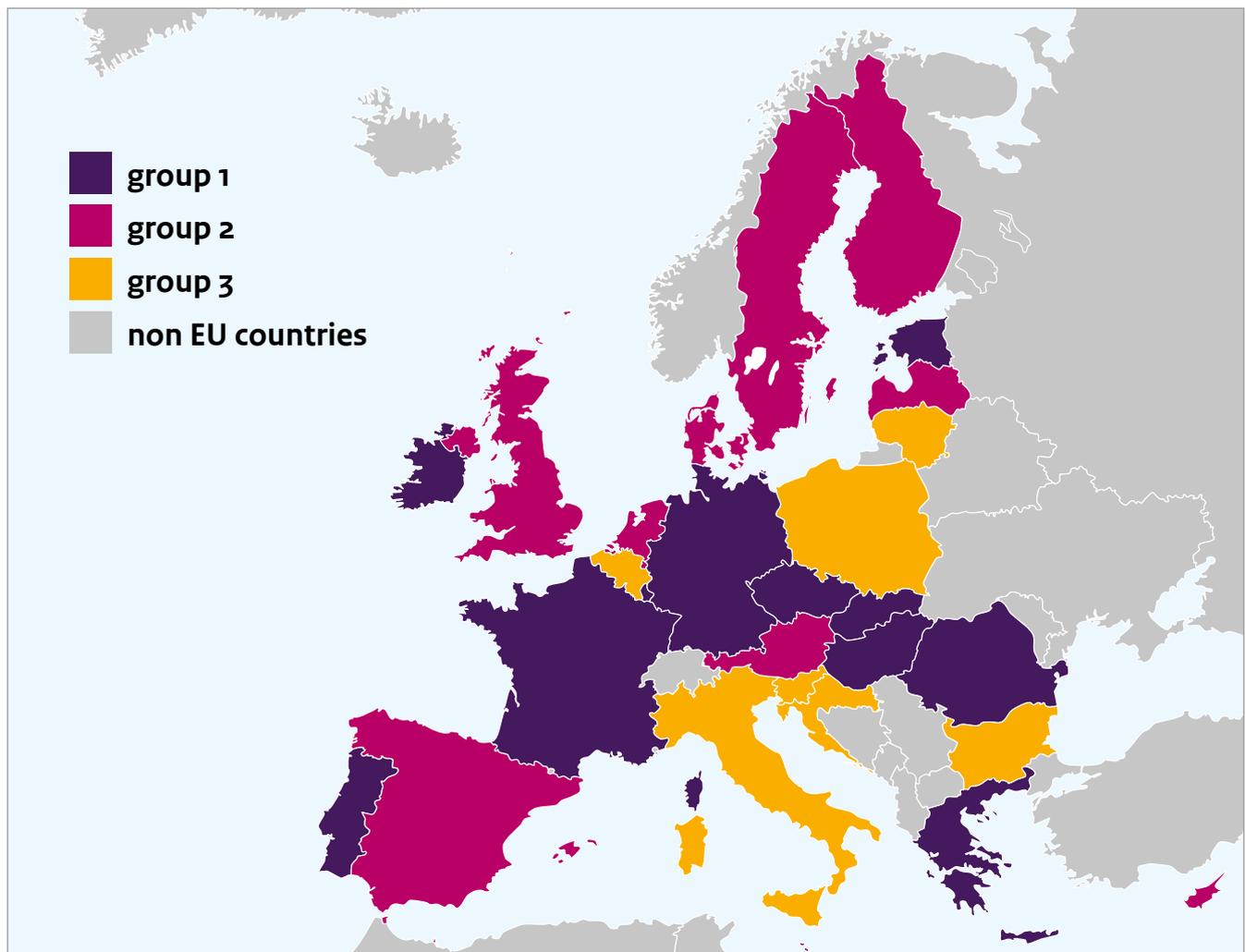
Italy: For all low frequency sources other than power lines, the reference levels and basic restrictions in the EU recommendation apply. For 50-hertz electric and magnetic fields from power lines and associated installations, the reference level in the EU recommendation may not be exceeded. In addition, a precautionary 'attention value' and 'quality goal' apply to 24-hour median exposure in homes, playgrounds, schools and places where people can stay for more than four hours. The 'attention value' of 10% of the EU reference level for magnetic flux density applies to existing situations. The 'quality goal' of 3% of the EU reference level for magnetic flux density applies to new situations. An even stricter limit for magnetic flux density (0.2% of the reference level) was adopted in three regions before the federal law came into force. This too applies to power lines near homes, schools and other places where people may stay for more than 4 hours per day.

Lithuania: A limit of 10% (electric field) or 20% (magnetic field) of the reference level in the EU recommendation applies inside residential and public buildings. A limit of 20% (electric field) or 40% (magnetic field) of the reference level in the EU recommendation applies to the living environment outside buildings.

Poland: A limit of 20% (electric field) or 75% (magnetic field) of the reference level in the EU recommendation applies to residential areas.

Slovenia: A limit of 10% of the reference level in the EU recommendation applies to electric and magnetic fields from new or modified sources near homes, schools, kindergartens, hospitals, sanatoria, playgrounds, parks, recreational areas, public buildings and buildings with a tourist destination. For other locations, limits equal to the reference levels in the EU recommendation apply.

Figure 1 Overview of limits for exposure of the general population to power frequency EMF in the EU. Group 1 (purple): legal limits derived from EU recommendation, precautionary policy in some countries; Group 2 (pink): no legal limits or limits less strict than in EU recommendation, precautionary policy in some countries; Group 3 (yellow): stricter limits than in EU recommendation.



Other countries

Different approaches to limiting exposure to power frequency EMF also exist in industrialised countries outside Europe. Seven examples are given below and further details on exposure limits can be found in **Table 1**.

Australia: No official government regulation or guidelines for exposure of the general population to EMF with frequencies lower than 3 kilohertz are currently in place. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) has stated that the ICNIRP low frequency guidelines are consistent with its interpretation of the scientific basis for the protection of the general public from exposure to low frequency EMF. The grid operators have a 'prudent avoidance' policy to take reasonable steps to limit field exposures from new facilities (overhead power lines, underground cables and substations) at no cost or very low cost while not unduly compromising other issues such as worker safety, site availability, reliability and environmental impact.

China: A national standard for protection of the general population under the Environmental Protection Law sets limits for environmental exposure to EMF, but does not apply to household appliances. The limits for power frequency magnetic fields equal the reference levels in the EU recommendation up to 800 hertz, but are lower for frequencies greater than 800 hertz. For electric fields the limits are lower than the reference levels in the EU recommendation for all frequencies. The standard also cites the precautionary principle and encourages facility and equipment owners to take effective measures to reduce public exposure.

India: There is no national regulation of the strength of power frequency EMF. Technical standards for the electricity supply sector give minimal distances to buildings, but these measures are related to electrical safety.

Japan: Ministerial regulations for technical standards of electrical equipment and railways limit power frequency magnetic fields to the reference level in the 2010 ICNIRP guidelines (200 microtesla at 50 hertz). The limit for power frequency electric fields (3000 volt per metre at 50 hertz) is lower than that in the ICNIRP guidelines and EU recommendation and meant to prevent electric shocks.

Russia: General rules for the protection are set in a 1999 framework law. Exposure limits for specific frequency ranges are set in so-called 'Hygienic-epidemiological standards'. The public exposure limit for power frequency magnetic fields is 5% of the reference level in the EU recommendation for living quarters, preschool, children's, general and medical institutions; 10% of the reference level in the EU recommendation for non-residential parts of residential buildings and in public and administrative buildings; 20% of the reference level in the EU recommendation in inhabited areas outside residential built-up areas; equal to the reference level in the EU recommendation in non-populated areas with occasional stay of people.

Switzerland: An Ordinance relating to Protection from Non-Ionising Radiation has been in force since 2000. Exposure limits identical to the reference levels in the EU recommendation apply to all areas accessible to the public. A stricter, precautionary limit on magnetic flux density of 1% of the reference level in the EU recommendation applies at so called places of sensitive use (for example apartments, schools, children's playgrounds) to the following classes of installations, unless the owner can prove that all technically possible and economically acceptable measures to reduce exposure have been taken: new high voltage power lines (overhead and cables); significant modification of existing high voltage power lines; existing and new transformers and substations. For existing high voltage power lines, the phase order has to be optimised when the precautionary limit on magnetic flux density is exceeded.

United States: No federal legislation is in force. In some states (Colorado, Connecticut, Hawaii, Maryland, Ohio), variations on the 'prudent avoidance' principle have been adopted. This means that exposure of the public to EMF of 60 hertz must be limited at reasonable cost. In other states, fixed limits for the electric or magnetic field of power lines are set, varying from 20% to 240% of the reference level in the EU recommendation (Florida, Minnesota, Montana, New Jersey, New York, Oregon).

Exposure of the general public, radiofrequency fields

European Union

Because the EU recommendation is not legally binding, EMF policy in member states can be divided into three different approaches. Details on exposure limits per member state can be found in **Table 1** and a visual overview in **Figure 2**. In the **first group** of member states the EU recommendation has been transposed in binding national legislation or national policy. This means that the basic restrictions and reference levels must be applied. Member states in this group are *Cyprus, Czech Republic, Estonia, Finland, France, Hungary, Ireland, Malta, Portugal, Romania and Spain*. In *Germany* and *Slovakia* the reference levels have become *de facto* exposure limits. In *France* there is an additional legal obligation to provide information on options for exposure reduction when selling or promoting a mobile phone and to provide citizens with measurement results for the strength of radiofrequency EMF in their homes or in public buildings.

In the **second group** of member states, the national limits based on the EU recommendation or ICNIRP are not binding, there are more lenient limits or there is no regulation. Member states in this group are *Austria, Denmark, Latvia, the Netherlands, Sweden and the United Kingdom*. In some countries, for example the Netherlands and the United Kingdom, telecommunication companies have signed up to a voluntary code to respect the limits in the EU recommendation in places accessible to the public. In the United Kingdom the national planning policy framework for local government also requires that applications for expansion of base stations certify that these limits will not be exceeded.

In the **third group** of member states, there are stricter reference levels and/or basic restrictions based on the precautionary principle and/or due to public pressure. The limits chosen are sometimes based on the principle 'as low as reasonably achievable without endangering service'. One practical choice for stricter limits can be to adopt the lower limit for interference in the European standards for electromagnetic compatibility (for example in Belgium). In other countries the reasons for particular limits are unclear or arbitrary (for example in Greece and Italy). In some member states the stricter reference levels are applied as exposure limits that may not be exceeded. Since there is a great diversity in particular rules and limits, a summary is given per member state:

Belgium: The advertising and sale of mobile phones specially designed for children younger than 7 years is prohibited. For all other phones, information must be provided on specific absorption rate and possibilities to lower exposure.

Regulation of exposure limits in Belgium is a matter for the three devolved regions. In Flanders, the limit for electrical field strength per antenna for telecommunication is 7% of the reference level in the EU recommendation in places of stay like homes, schools, rest homes and nurseries. The maximum exposure in all publicly accessible places is 50% of the reference level for frequencies between 10 megahertz and 10 gigahertz. The Brussels Region limits total exposure in residences for frequencies between 100 kilohertz and 300 gigahertz to a power density of 2% of the reference level in the EU recommendation (corresponding with 15% for the electric field strength). For the same frequency range, Wallonia sets a fixed limit for the electrical field strength per antenna in residences which is 7% of the reference level at 900 megahertz.

Bulgaria: Fixed limits for electrical field strength and power density are set. Their percentage of the reference levels in the EU recommendation decreases with frequency. For power density it is 2% at 900 megahertz and less than 2% for higher frequencies.

Croatia: For public spaces in general, fixed limits for the electric and magnetic fields are applied which are 95% of the reference levels in the EU recommendation (90% for power density). For 'sensitive areas' (homes, offices, schools, playgrounds, kindergartens, maternity wards, hospitals, homes for the elderly and disabled and tourist accommodations), the limits for the electric and magnetic field are 40% of the reference levels in the EU recommendation (16% for power density).

Greece: The law on electronic communications sets basic restrictions of 70% of those in the EU recommendation and 60% when antenna stations are located closer than 300 metres from the property boundaries of schools, kindergartens, hospitals or eldercare facilities. Installation of mobile phone antenna stations is not allowed within the property boundaries of aforementioned facilities. Reference levels calculated from these two basic restrictions are 84% and 77% of the reference levels in the EU recommendation (70% and 60% for power density).

Italy: For EMF from high frequency sources other than fixed systems for telecommunication and radio or TV broadcasting, the reference levels and basic restrictions in the EU recommendation apply. For EMF from fixed systems for telecommunication and radio or TV broadcasting, there are exposure limits in terms of the strength of environmental EMF that may not be exceeded. In contrast with the limits in the EU recommendation, these are constant (not frequency dependent) between 3 megahertz and 3 gigahertz.

The exposure limit for electric field strength at 900 megahertz is 49% of the reference level in the EU recommendation (22% for power density). In homes, schools, playgrounds and places where people may stay for longer than four hours, the ‘attention value’ for electric field strength is 15% of the reference level in the EU recommendation at 900 megahertz (2% for power density). The ‘quality goal’ for highly frequented outdoor areas is identical to the attention value.

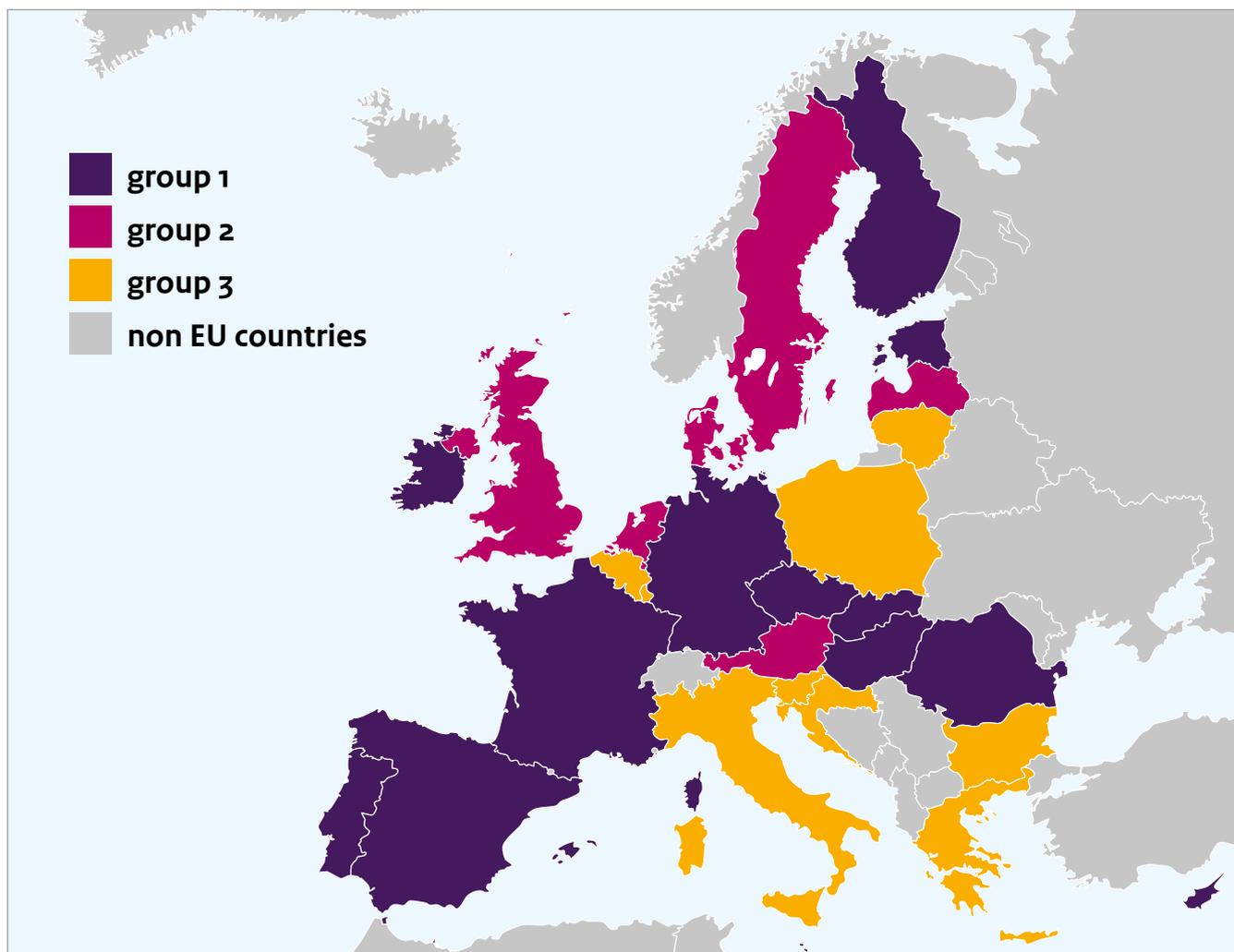
Lithuania: There are limits for EMF with frequencies between 10 megahertz and 300 gigahertz inside and surrounding residential and public buildings which may not be exceeded and are lower than the reference levels in the EU recommendation. The percentage varies with frequency, but for power density the limit is 10% of the EU reference level at 900 megahertz.

Luxemburg: Precautionary policy is applied to mobile telephony through a law on classified locations and technical standards. These set a fixed exposure limit for the electrical field strength per radiating element for antennas with a power of 100 watt and higher which is 7% of the reference level in the EU recommendation at 900 megahertz. The limit for other antennas and for the total number of antenna elements in one location equals the reference level in the EU recommendation.

Poland: In locations that are accessible to the public, frequency-dependent exposure limits lower than the reference levels in the EU recommendation are set for electrical field strength and power density. At 900 megahertz the limit for electrical field strength is 17% of the reference level in the EU recommendation (2% for power density).

Figure 2 Overview of limits for exposure of the general population to radiofrequency EMF in the EU.

Group 1 (purple): legal limits derived from EU recommendation; Group 2 (pink): no legal limits or limits less strict than in EU recommendation; Group 3 (yellow): stricter limits than in EU recommendation.



Slovenia: For frequencies higher than 10 kilohertz, exposure limits for electric and magnetic field strength of 31% of the reference levels in the EU recommendation (10% for power density) apply in 'sensitive areas' such as homes, schools and hospitals. In all other locations the reference levels in the EU recommendation are applied as *de facto* exposure limits that may not be exceeded.

Other countries

Industrialised countries outside the EU also have different ways of limiting exposure of the public to radiofrequency EMF. Seven examples are given below and further details on exposure limits can be found in **Table 1**.

Australia: The mandatory basic restrictions and reference levels in the national radiation protection and radiocommunication standards are identical to those in the EU recommendation.

China: A national standard for protection of the general population under the Environmental Protection Law sets limits for environmental exposure to EMF, but does not apply to wireless communication terminal equipment. The limits are lower than the reference levels in the EU recommendation, but the percentage varies with frequency. At 900 megahertz the limit for electric field strength is 29% of the reference level in the EU recommendation (9% for power density). The standard also cites the precautionary principle and encourages facility and equipment owners to take effective measures to reduce public exposure. The basic restrictions for mobile phones in a separate standard are identical to those in the EU recommendation.

India: A ministerial memorandum amending the Unified Access Service License sets limits on exposure of the general public to EMF from telecommunication base stations. The limit is 33% of the reference levels in the EU recommendation for electric and magnetic field strength and 10 % for power density. Government-approved interministerial committee recommendations set a limit on the specific absorption rate for mobile handsets which is 80% of the basic restriction for local exposure of the head in the EU recommendation.

Japan: The ministerial radiofrequency radiation protection guidelines for human exposure to EMF contain a mandatory basic restriction for mobile phones which is identical to that in the EU recommendation. The guidelines also contain mandatory basic restrictions with reference levels for the strength of EMF from mobile phone base stations, which are almost identical to the reference levels in the EU recommendation.

Russia: General conditions for protection of the population are set in a 1999 framework law. Limits for specific frequency ranges are set in subsequent 'Hygienic-epidemiological requirements'. The exposure limit for power density for EMF with frequencies between 300 megahertz and 300 gigahertz in and around residential buildings and inside public and industrial premises is 2% of the reference level in the EU recommendation. The reason is to prevent biological effects that are not generally seen as a health risk in Western countries. There is no basic restriction in terms of specific absorption rate, but there is a limit on the plain wave power density of mobile phones which is 22% of the reference level in the EU recommendation.

Switzerland: An Ordinance relating to Non-Ionising Radiation is in force since 2000. Mandatory exposure limits identical to the reference levels in the EU recommendation apply in all areas accessible to the public. A stricter, precautionary limit for the electric field strength of approximately 10 % of the reference level in the EU Recommendation applies at so called places of sensitive use (for example apartments, schools, children's playgrounds) near mobile phone antennae, broadcasting and radar installations.

United States: The basic restriction for whole body exposure in federal legislation for radio transmitters is identical to that in the EU recommendation. However, the reference levels are higher because a different model is used to calculate them. At 900 megahertz the difference is 15% and 14% for the electric and magnetic field strength respectively (33% for power density). The reference levels are applied as *de facto* exposure limits for non-portable devices. For portable devices close to the body, the mandatory basic restriction for local exposure of all parts of the body except the extremities is 80% of the basic restriction for head and trunk in the EU recommendation. The basic restriction for the extremities (hands, wrists, ankles, feet, outer ears) is identical to the basic restriction for limbs in the EU recommendation.

In addition to the above legal obligations, in Australia, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, India, Italy, Luxemburg, the Netherlands, Spain, Sweden, Russia, Switzerland, the United Kingdom and the United States the government or national scientific organisations have published advice on how to reduce exposure to radiofrequency EMF from mobile phones, such as limiting calling time, using earpieces or speakers, not holding the phone close to the body, avoiding calls in areas with poor reception and texting instead of calling.

Occupational exposure, Power frequency fields

European Union

In all member states of the EU, protection of workers against the risks of EMF is regulated by national legislation based on directive 2013/35/EU. The directive contains general rules and appendices with exposure limits. The directive distinguishes three layers of action levels for low frequency magnetic fields: low action levels related to sensory effects exposure limit values (equivalent to ICNIRP's 2010 basic restrictions for the central nervous system) and high action levels and limb action levels related to health effects exposure limit values (equivalent to ICNIRP's 2010 basic restrictions for the peripheral nervous system). When the action levels are exceeded, this is an indication that the related exposure limit values could be exceeded.

The directive sets minimum requirements, but allows member states to set stricter rules or limits, which are detailed below and in **Table 2**. The directive also gives member states the possibility to apply a conditional exemption from the exposure limits (but not from the general rules) for worker exposure related to magnetic resonance imaging (MRI) for patients in the health sector, to apply a different but equivalent or more specific protection system for military personnel and to allow the exposure limits to be temporarily exceeded under certain conditions for specific sectors or activities in duly justified circumstances. Details of whether and how individual member states have applied these possibilities for exemptions can be found in **Table 2**. Two member states have action levels and/or exposure limit values that differ from those in the EU directive:

Czech Republic: For EMF with frequencies from 1 hertz to 10 megahertz, there is only one action level, which is equivalent to the low action level in the EU directive. Nevertheless, there are still two levels of exposure limit values for the internal electric field, the higher for exposure of the head and the lower for exposure of the rest of the body.

Poland: For EMF with frequencies between 0 and 300 gigahertz, there are six sets of action levels delimiting a 'danger zone', 'threat zone' and 'intermediate zone', action levels for local exposure of extremities and ancillary action levels for peak levels for modulated fields. The two levels of exposure limit values for the internal electric field are identical to the sensory effects and health effects exposure limit values in the EU directive, but have been extended to frequencies between 0 and 1 hertz based on the 2014 ICNIRP guidelines for magnetic fields below 1 hertz.

Other countries

Australia: There are radiation protection regulations which are only applicable to Commonwealth employees and set limits on occupational exposure to EMF from 'controlled apparatus', that is, specified categories of devices that could cause EMF which exceed these limits (for example induction heaters). Its reference levels and basic restrictions are identical to those in the 2009 and 2010 ICNIRP guidelines on static and low frequency fields. They therefore have the same basis as the limits in the EU directive, but apply to a narrower range of devices. The reference levels equal the low action levels in the EU directive. For non-Commonwealth employees there is no official government regulation but the ARPANSA advice on the ICNIRP guidelines also applies to workers.

China: The national standard with occupational exposure limits for physical agents in the workplace has a limit of 5 kilovolt per metre for exposure to power frequency electric fields. There are no occupational limits for power frequency magnetic fields.

India: There are no legally binding limits on occupational exposure to power frequency EMF. Protection of workers would therefore fall under general health and safety legislation such as the Factories Act.

Japan: There are no legally binding limits on occupational exposure to power frequency EMF. The Japan Society for Occupational Health has recommended occupational exposure limits for EMF in terms of the strength of external electric and magnetic field, which are identical to the low action levels in the EU directive.

Russia: A national standard sets limits for power frequency magnetic fields, which depend on the exposure duration. For exposures shorter than 1 hour, the limit for whole body exposure is 33% of the high action level, but for 8 hours it is 2% of the high action level in the EU directive. The limit for 'limbs only' exposure is four to ten times higher than the limit for whole body exposure.

Switzerland: The federal law on accident insurance gives general rules to prevent illness caused by physical agents. The national accident insurer has specified that exposure limits identical to the occupational reference levels in the 1998 ICNIRP guidelines may not be exceeded. For power frequency, the limit is 50% of the low action level in the EU directive for the magnetic field and 100% for the electric field.

United States: There are no legal limits for occupational exposure to power frequency EMF. The American Conference of Governmental Industrial Hygienists has recommended ‘threshold limit values’ which are 20% of the high action level in EU directive for magnetic fields but 125% of the high action level for electric fields. These are to be used by trained industrial hygienists as a supplement to their occupational safety and health program.

NATO: The standardisation treaty for protection of military personnel of the North Atlantic Treaty Organization (NATO) refers to a standard of the Institute of Electrical and

Electronics Engineers (IEEE). The level of the IEEE equivalent of exposure limit values for the induced electric field in the brain is similar to that of the sensory effects exposure limit values in the EU directive. The IEEE equivalent of exposure limit values for the rest of the body are less strict than the health effects exposure limit values in the EU directive (263% at 50 hertz for restricted working environments). The corresponding IEEE equivalent of action levels are less strict than the EU high action levels, due to different dosimetric considerations and safety factors. The IEEE limits for contact currents are also less strict than those in the EU directive.

Occupational exposure, radiofrequency fields

European Union

In all member states of the EU, protection of workers against the risks of EMF is regulated by national legislation based on directive 2013/35/EU. The directive sets minimum requirements, but allows member states to set stricter rules or limits and conditional exemptions, which are detailed below and in **Table 2**. For radiofrequency fields, the EU directive has action levels in terms of the electric field strength, magnetic flux density and power density outside the body, which are related to the health effects exposure limit values (equivalent to ICNIRP occupational basic restrictions for specific absorption rate and power density). One member state has action levels that differ from those in the EU directive:

Poland: For EMF with frequencies between 0 and 300 gigahertz, there are six sets of action levels delimiting a ‘danger zone’, ‘threat zone’ and ‘intermediate zone’, action levels for local exposure of extremities and ancillary action levels for peak levels for modulated fields. The exposure limit values for specific absorption rate are identical to the health effects exposure limit values in the EU directive.

Other countries

Australia: The national radiation protection regulations, which are only applicable to Commonwealth employees, set limits on occupational exposure to EMF from ‘controlled apparatus’, that is specified categories of devices that could cause EMF exceeding these limits (for example diathermy equipment). Its reference levels and basic restrictions are set by the national radiation protection standard and are identical to those in the 1998 ICNIRP guidelines. They therefore have the same basis as the limits in the EU directive, but apply to a narrower range of devices. In addition, a national radiocommunications standard limits the exposure of ‘aware users’ of mobile radiofrequency devices to basic restrictions identical to those in the EU directive.

China: The national standard with occupational exposure limits for physical agents in the workplace has limits for radiofrequency EMF with frequencies from 100 kilohertz to 300 gigahertz. For frequencies from 100 kilohertz to 300 megahertz, exposure limits are 8% to 41% of the action levels in the EU directive. For frequencies from 300 megahertz to 300 gigahertz, exposure limits do not vary with frequency but depend on the duration of exposure. At 900 megahertz the limit for whole body exposure varies from 222% of the EU action level for short exposure to 1% of the EU action level for 8-hour average exposure. Limits for partial body exposure are ten times higher than those for whole body exposure.

India: There are no legally binding limits on occupational exposure to radiofrequency EMF. Protection of workers would therefore fall under general health and safety legislation such as the Factories Act.

Japan: There are no legally binding limits on occupational exposure to radiofrequency EMF. The Japan Society for Occupational Health has recommended occupational exposure limits for EMF in terms of the strength of external electric and magnetic field and power density. These are identical to the thermal effects action levels in the EU directive.

Russia: The relevant 'Hygienic-epidemiological requirements' set a fixed limit per frequency band for maximum exposure to radiofrequency EMF with frequencies between 3 kilohertz and 300 gigahertz which is 44% of the action value for power density in the EU directive at 900 megahertz for whole body exposure and 222% for peak exposure of limbs. There are also lower time-dependent limits.

Switzerland: The federal law on accident insurance gives general rules to prevent illness caused by physical agents. The national accident insurer has specified that exposure limits identical to the action levels in the EU directive may not be exceeded.

United States: The equivalent of exposure limit values for whole body and for local exposure of the extremities (hands, wrists, ankles, feet, outer ears) in the federal legislation for transmitters are identical to those for whole body and for local exposure of limbs in the EU directive. The equivalent of exposure limit values for local exposure of all parts of the body except the extremities is 80% of that in the EU directive. The equivalent of action levels for electric and magnetic field strength are 18% higher than those in the EU directive (33% for power density), because a different model is used to calculate them. The equivalent of exposure limit values in the United States must be used for portable devices close to the body. The action levels are applied as *de facto* exposure limits for non-portable devices.

NATO: The standardisation treaty for protection of military personnel of the North Atlantic Treaty Organization (NATO) refers to a standard of the Institute of Electrical and Electronics Engineers (IEEE) with the same level of the equivalent of exposure limit values and action levels as those in the federal legislation of the United States, with the exception of the IEEE equivalent of exposure limit values for local exposure of the head which is identical to that in the EU directive. The limits for contact currents are higher than those in the EU directive.

Table 1 Reference levels or exposure limits for the general public for electromagnetic fields in inhabited areas in member states of the European Union and selected industrial nations outside the European Union (situation July 2017)

| Country: | 50 Hz | | 900 MHz | | | 1800 MHz | | | 2100 MHz | | |
|--------------------|-------------------------------|----------------------------|-------------------------------|----------------------------|---|-------------------------------|----------------------------|---|-------------------------------|----------------------------|---|
| | electric field strength (V/m) | magnetic flux density (μT) | electric field strength (V/m) | magnetic flux density (μT) | equivalent plain wave power density (W/m ²) | electric field strength (V/m) | magnetic flux density (μT) | equivalent plain wave power density (W/m ²) | electric field strength (V/m) | magnetic flux density (μT) | equivalent plain wave power density (W/m ²) |
| 1999/519/EC | 5000 | 100 | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Austria | [5000] | [100] ¹⁾ | [41] | [0.14] | [4.5] | [58] | [0.20] | [9] | [61] | [0.20] | [10] |
| Belgium | — | 10 ²⁾ | 21 ³⁾ | — | — | 29 ³⁾ | — | — | 31 ³⁾ | — | — |
| Bulgaria | — ⁴⁾ | — ⁴⁾ | — | — | 0.1 | — | — | 0.1 | — | — | 0.1 |
| Croatia | 2000 ⁵⁾ | 40 ⁵⁾ | 17 ⁵⁾ | 0.055 ⁵⁾ | 0.72 ⁵⁾ | 23 ⁵⁾ | 0.078 ⁵⁾ | 1.4 ⁵⁾ | 25 ⁵⁾ | 0.084 ⁵⁾ | 1.7 ⁵⁾ |
| Cyprus | [5000] | [100] | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Czech Republic | 2000 | 200 | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Denmark | — | — ⁶⁾ | — | — | — | — | — | — | — | — | — |
| Estonia | 5000 | 100 | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Finland | [5000] | [100] ⁷⁾ | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| France | 5000 ⁸⁾ | 100 ⁸⁾ | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Germany | 5000 ⁹⁾ | 100 ⁹⁾ | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Greece | 5000 | 100 | 32 ¹⁰⁾ | 0.11 ¹⁰⁾ | 2.7 ¹⁰⁾ | 45 ¹⁰⁾ | 0.15 ¹⁰⁾ | 5.4 ¹⁰⁾ | 47 ¹⁰⁾ | 0.16 ¹⁰⁾ | 6 ¹⁰⁾ |
| Hungary | 5000 | 100 | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Ireland | 5000 ¹¹⁾ | 100 ¹¹⁾ | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Italy | — | 3 ¹²⁾ | 6 ¹³⁾ | 0.02 ¹³⁾ | 0.1 ¹³⁾ | 6 ¹³⁾ | 0.02 ¹³⁾ | 0.1 ¹³⁾ | 6 ¹³⁾ | 0.02 ¹³⁾ | 0.1 ¹³⁾ |
| Latvia | — | — | — | — | — | — | — | — | — | — | — |
| Lithuania | 500 ¹⁴⁾ | 20 ¹⁴⁾ | — | — | 0.45 | — | — | 0.9 | — | — | 1 |
| Luxemburg | 5000 ¹⁵⁾ | 100 ¹⁵⁾ | 41 ¹⁶⁾ | 0.14 | 4.5 | 58 ¹⁶⁾ | 0.20 | 9 | 61 ¹⁶⁾ | 0.20 | 10 |
| Malta | [5000] | [100] | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Netherlands | [5000] ¹⁷⁾ | [100] ¹⁷⁾ | — | — | — | — | — | — | — | — | — |
| Poland | 1000 | 75 | 7 | — | 0.1 | 7 | — | 0.1 | 7 | — | 0.1 |
| Portugal | 5000 | 100 | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Romania | 5000 | 100 | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Slovakia | 5000 | 100 | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Slovenia | 500 ¹⁸⁾ | 10 ¹⁸⁾ | 13 ¹⁸⁾ | 0.04 ¹⁸⁾ | 0.45 ¹⁸⁾ | 18 ¹⁸⁾ | 0.06 ¹⁸⁾ | 0.9 ¹⁸⁾ | 19 ¹⁸⁾ | 0.06 ¹⁸⁾ | 1 ¹⁸⁾ |
| Spain | [5000] ¹⁹⁾ | [100] ¹⁹⁾ | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| Sweden | [5000] | [100] | [41] | [0.14] | [4.5] | [58] | [0.20] | [9] | [61] | [0.20] | [10] |
| United Kingdom | [9000] | [360] | [41] | [0.14] | [4.5] | [58] | [0.20] | [9] | [61] | [0.20] | [10] |
| Australia | — | — | 41 | 0.14 | 4.5 | 58 | 0.20 | 9 | 61 | 0.20 | 10 |
| China | 4000 | 100 | 12 | 0.04 | 0.4 | 12 | 0.04 | 0.4 | 12 | 0.04 | 0.4 |
| India | — | — | 13 | 0.041 | 0.45 | 18 | 0.058 | 0.9 | 20 | 0.063 | 1.1 |
| Japan | 3000 ²⁰⁾ | 200 ²⁰⁾ | 48 | 0.16 | 6 | 61 | 0.20 | 10 | 61 | 0.20 | 10 |
| Russia | 500 | 5 ²¹⁾ | — | — | 0.1 | — | — | 0.1 | — | — | 0.1 |
| Switzerland | — | 1 ²²⁾ | 4 ²³⁾ | — | — | 6 ²³⁾ | — | — | 6 ²³⁾ | — | — |
| U.S.A. | — ²⁴⁾ | — ²⁴⁾ | — | — | 6 | — | — | 10 | — | — | 10 |

Legend to Table 1: All limits are given as root mean square (rms) value. Where necessary magnetic flux density was calculated from magnetic field strength using a magnetic permeability of $4\pi \times 10^{-7}$ H/m. Normal typeface: reference level for the external field in the meaning of Recommendation 1999/519/EC, derived from basic restriction. Application is mandatory unless value is in square brackets. Italic typeface: mandatory exposure limit in terms of the external field outside the body. Radiofrequency limits are standardised to approximate mobile telecommunication frequency bands in Europe, but actual network frequencies may vary.

Notes:

- 1) For new power lines requiring environmental impact assessment, authorities usually require compliance with Swiss limit of $1 \mu\text{T}$
- 2) Flanders: indoor environment limit $10 \mu\text{T}$, quality aim $0.2 \mu\text{T}$, government recommendation for new situations near power line $0.4 \mu\text{T}$; Brussels: $0.4 \mu\text{T}$ near new transformers and $100 \mu\text{T}$ near existing transformers; Wallonia: 5000 V/m and $100 \mu\text{T}$ near transformers
- 3) Limit in table is for publicly accessible places in Flanders, limit per antenna in places of stay 3.0 V/m at 900 MHz , 4.2 V/m at 1800 MHz , 4.5 V/m at 2100 MHz ; Wallonia: limit per antenna 3 V/m ; Brussels: limit per location 0.096 W/m^2 at 900 MHz , 0.19 W/m^2 at 1800 MHz , 0.22 W/m^2 at 2100 MHz
- 4) Minimal distances to power lines and to electrical distribution systems, differentiated by voltage; separate regulation for video display units
- 5) In homes, offices, schools, kindergartens, playgrounds, hospitals, care homes, tourist facilities; for other public spaces reference levels in 1999/519/EC apply
- 6) Danish Health Authority recommends that new homes and new institutions where children stay should not be built close to existing power lines and new power lines should not be built close to existing homes and institutions where children stay
- 7) Radiation safety authority recommends avoiding construction of permanent residences and premises meant for children in areas where magnetic flux density exceeds $0.4 \mu\text{T}$
- 8) For new or modified installations; there is also government advice to local authorities not to create new establishments with children in zones with magnetic flux density above $1 \mu\text{T}$
- 9) For new or modified installations exhaust all possibilities to minimise EMF; new power lines $\geq 220 \text{ kV}$ may not span buildings for long-term stay of people
- 10) For antenna stations closer than 300 m to sensitive locations (schools, kindergartens, hospitals, care homes); elsewhere 35 V/m , $0.11 \mu\text{T}$, 3.1 W/m^2 at 900 MHz ; 49 V/m , $0.16 \mu\text{T}$, 6.3 W/m^2 at 1800 MHz ; 51 V/m , $0.17 \mu\text{T}$, 7 W/m^2 at 2100 MHz
- 11) For new energy infrastructure, State Companies and energy developers must comply with ICNIRP limits and associated EU Recommendations as an intrinsic part of the planning process
- 12) For new situations with power lines near homes, schools, playgrounds, places with stay > 4 hours; $10 \mu\text{T}$ for existing situations near homes, schools, playgrounds, places with stay > 4 hours; $100 \mu\text{T}$ and 5000 kV/m for all other exposures from power lines
- 13) EMF from fixed systems for telecommunication and radio or TV broadcasting near homes and their outdoor annexes, in schools and playgrounds, in places with stay greater than 4 hours; elsewhere 20 V/m , $0.06 \mu\text{T}$, 1 W/m^2
- 14) Inside residential and public buildings; limits for living environment outside residential and public buildings 1000 V/m , $40 \mu\text{T}$
- 15) Security conditions for electricity lines, there are also voluntary minimal distances to power lines for new developments
- 16) Limit per antenna at places where people can stay 3.0 V/m , applies to antennas with power of 100 W and higher
- 17) Ministerial recommendation: create no new situations of long-term stay of children in magnetic flux density greater than $0.4 \mu\text{T}$ around overhead power lines, otherwise reference level in 1999/519/EC applies
- 18) Applies to homes, hospitals, health resorts, public buildings, tourism buildings, schools, nurseries, playgrounds, parks, recreational areas; otherwise limit for external electric and magnetic field strength equal to reference level in 1999/519/EC; for power frequency limits apply to new or reconstructed sources only
- 19) No binding national limits for 50 Hz fields, but in practice electricity companies and the authorities apply the limits in 1999/519/EC
- 20) Limit listed is for 50 Hz fields, power frequency is 50 Hz in East Japan and 60 Hz in West Japan
- 21) Limit for living quarters, children's, preschool, general and medical institutions; non-residential premises $10 \mu\text{T}$, inhabited areas outdoors $20 \mu\text{T}$, uninhabited areas $100 \mu\text{T}$
- 22) Limit at places of sensitive use (buildings in which persons regularly stay for longer periods, playgrounds) for all high voltage installations except existing powerlines; otherwise reference level in 1999/519/EC applies at all places accessible for the public
- 23) Limit at places of sensitive use (buildings in which persons regularly stay for longer periods, playgrounds) for individual antenna installations; otherwise reference level in 1999/519/EC applies at all places accessible for the public
- 24) Power frequency is 60 Hz ; no federal regulation, limits in some states, prudent avoidance policy in others (measures to reduce exposure at reasonable cost)

Table 2 Occupational reference levels or exposure limits for electromagnetic fields in member states of the European Union and selected industrial nations outside the European Union (situation July 2017)

| Country: | 50 Hz | | 900 MHz | | | conditional exemption from ELV for MRI | alternative protection system for armed forces | temporary exemption from ELV for specific sectors or activities |
|-------------------|---|---|-------------------------------|---|---|--|--|---|
| | electric field strength (high AL) (V/m) | magnetic flux density (high AL) (μT) | electric field strength (V/m) | magnetic flux density (μT) | equivalent plain wave power density (W/m^2) | | | |
| 2013/35/EU | 20000 | 6000 | 90 | 0.30 | — | yes | yes | yes |
| Austria | 20000 ¹⁾ | 6000 ¹⁾ | 90 ¹⁾ | 0.30 ¹⁾ | — | yes | no | yes ²⁾ |
| Belgium | 20000 | 6000 | 90 | 0.30 | — | yes | no | yes |
| Bulgaria | 20000 | 6000 | 90 | 0.30 | — | yes | yes (NATO) | no |
| Croatia | 20000 | 6000 | 90 | 0.30 | — | yes | yes | yes |
| Cyprus | 20000 | 6000 | 90 | 0.30 | — | yes | yes | yes |
| Czech Republic | 10000 | 1000 | 90 | 0.30 | 22.5 | no | no | no |
| Denmark | 20000 | 6000 | 90 | 0.30 | — | yes | no | no |
| Estonia | 20000 | 6000 | 90 | 0.30 | — | yes | yes (NATO) | no |
| Finland | 20000 | 6000 | 90 | 0.30 | — | yes | yes | yes |
| France | 20000 ³⁾ | 6000 ³⁾ | 90 ³⁾ | 0.30 ³⁾ | — | yes ⁴⁾ | no | no |
| Germany | 20000 | 6000 | 90 | 0.30 | — | yes ⁴⁾ | no | yes ⁴⁾ |
| Greece | 20000 | 6000 | 90 | 0.30 | — | yes | Yes (NATO) | Yes ⁵⁾ |
| Hungary | 20000 | 6000 | 90 | 0.30 | — | no ⁶⁾ | yes (NATO) | yes ⁶⁾ |
| Ireland | 20000 | 6000 | 90 | 0.30 | — | yes | no | no |
| Italy | 20000 | 6000 | 90 | 0.30 | — | no ⁷⁾ | yes | yes ⁷⁾ |
| Latvia | 20000 | 6000 | 90 | 0.30 | — | yes | yes | no |
| Lithuania | 20000 | 6000 | 90 | 0.30 | — | yes | yes ⁸⁾ | no |
| Luxemburg | 20000 | 6000 | 90 | 0.30 | — | yes ⁹⁾ | yes (NATO) ⁹⁾ | yes ⁹⁾ |
| Malta | 20000 | 6000 | 90 | 0.30 | — | yes | yes | yes |
| Netherlands | 20000 | 6000 | 90 | 0.30 | — | yes | yes | no |
| Poland | 10000 ¹⁰⁾ | 2000 ¹⁰⁾ | 60 ¹⁰⁾ | 0.20 ¹⁰⁾ | — | no | yes | no |
| Portugal | 20000 ¹¹⁾ | 6000 ¹¹⁾ | 90 ¹¹⁾ | 0.30 ¹¹⁾ | — | yes | yes | no |
| Romania | 20000 | 6000 | 90 | 0.30 | — | yes | yes | yes |
| Slovakia | 20000 | 6000 | 90 | 0.30 | — | yes | yes | yes |
| Slovenia | 20000 | 6000 | 90 | 0.30 | — | yes | yes | yes ¹²⁾ |
| Spain | 20000 | 6000 | 90 | 0.30 | — | yes | yes (NATO) | yes |
| Sweden | 20000 | 6000 | 90 | 0.30 | — | yes | yes | no |
| United Kingdom | 20000 | 6000 | 90 | 0.30 | — | yes | yes | yes ¹³⁾ |
| Australia | 10000 | 1000 | 92 | 0.31 | 22.5 | | | |
| China | 5000 | — | — | — | 50 ¹⁴⁾ | | | |
| India | — | — | — | — | — | | | |
| Japan | — ¹⁵⁾ | — ¹⁵⁾ | — ¹⁵⁾ | — ¹⁵⁾ | — ¹⁵⁾ | | | |
| Russia | — | 2000 ¹⁶⁾ | — | — | 10 ¹⁶⁾ | | | |
| Switzerland | 10000 ¹⁷⁾ | 500 ¹⁷⁾ | 90 ¹⁷⁾ | 0.30 ¹⁷⁾ | 22.5 ¹⁷⁾ | | | |
| U.S.A. | — ¹⁸⁾ | — ¹⁸⁾ | — | — | 30 | | | |

Legend to Table 2: All limits are given as root mean square (rms) value. Where necessary magnetic flux density was calculated from magnetic field strength using a magnetic permeability of $4\pi \times 10^7$ H/m. Normal typeface: action level (AL)/reference level for the external field in the meaning of Directive 2013/35/EU or ICNIRP guidelines, derived from exposure limit value (ELV)/basic restriction. Application is mandatory unless value is in square brackets. *Italic typeface: mandatory exposure limit in terms of the external field outside the body.*

Notes:

- 1) Limits in EU recommendation 1999/519/EC apply to pregnant workers; AL may not be exceeded for workers younger than 18 years; sensory effects ELV may only be exceeded for resistance welding and electricity supply sector
- 2) Sensory and health effects ELV may be temporarily exceeded for workers in delimited areas in establishments for generation, transport and distribution of electrical energy
- 3) Limits in EU recommendation 1999/519/EC apply to pregnant workers; sensory effects ELV may not be exceeded for workers younger than 18 years
- 4) Exemption with additional obligations to those in Directive 2013/35/EU
- 5) For any temporary exemption from ELV for a specific sector or activity, the National Occupational Health & Safety Council shall give its expert opinion beforehand
- 6) Regional radiation safety officer may allow exposure of workers to exceed health effects ELV in specific circumstances where state-of-the-art technical and organisational protection measures have been implemented; annexes to national legislation contain list of equipment requiring risk assessment approval, including MRI
- 7) Ministers of Labour and Social Policy and of Health may grant a conditional and temporary derogation at the request of the employer, with additional requirements for MRI
- 8) Scope extended: military personnel or national security, public security and customs officials as determined by Lithuanian intelligence regulations
- 9) Employer is obliged to check the appropriateness of the measures taken with an approved expert acting within the competences and authority of the labour inspectorate
- 10) Values listed are for basic 'threat' AL, there are also higher 'danger' AL, lower 'intermediate' AL for indirect effects and ancillary AL for modulated fields
- 11) Employer shall ensure that the exposure of workers to electromagnetic fields is reduced to the lowest possible level, but in any case it should not exceed ELV
- 12) Sensory and health effects ELV may be temporarily exceeded for workers in police, other units and services for protection, rescue and relief in specific circumstances
- 13) Temporary conditional exemption from ELV for electrolysis, dielectric heating, induction heating, manual resistance welding, MRI equipment other than that for patients
- 14) Limit for short exposures, for longer exposures limits decrease down to 0.5 W/m² (continuous wave) or 0.25 W/m² (pulsed) for 8 hours with whole body exposure
- 15) No legal limits for workers, Japan Society for Occupational Health has recommended occupational exposure limits in terms of the strength of external electric and magnetic field and power density identical to the low action levels and thermal effects action levels in the EU directive
- 16) Limit for exposures shorter than 1 hour, for longer exposures limits decrease down to 100 µT for 8 hours; for radiofrequency fields there are also limits on exposure x time
- 17) For pregnant workers, exposure limits identical to the reference levels in EU recommendation 1999/519/EC apply
- 18) No legal limits for workers, American Conference of Governmental Industrial Hygienists has recommended 'threshold limit values' of 25000 V/m and 1000 µT at 60 Hz as guidelines to assist in the control of potential workplace health hazards

.....
Rianne Stam

Colophon

The author thanks the many scientific and policy experts who contributed information and reviewed a draft version of the document.

Author: Rianne Stam

© RIVM 2017

Parts of this publication may be reproduced, provided acknowledgement is given to the 'National Institute for Public Health and the Environment, RIVM', along with the title and year of publication.

Published by:

**National Institute for Public Health
and the Environment, RIVM**

PO Box 1 | 3720 BA Bilthoven
The Netherlands
www.rivm.nl/en

January 2018

Committed to *health and sustainability*