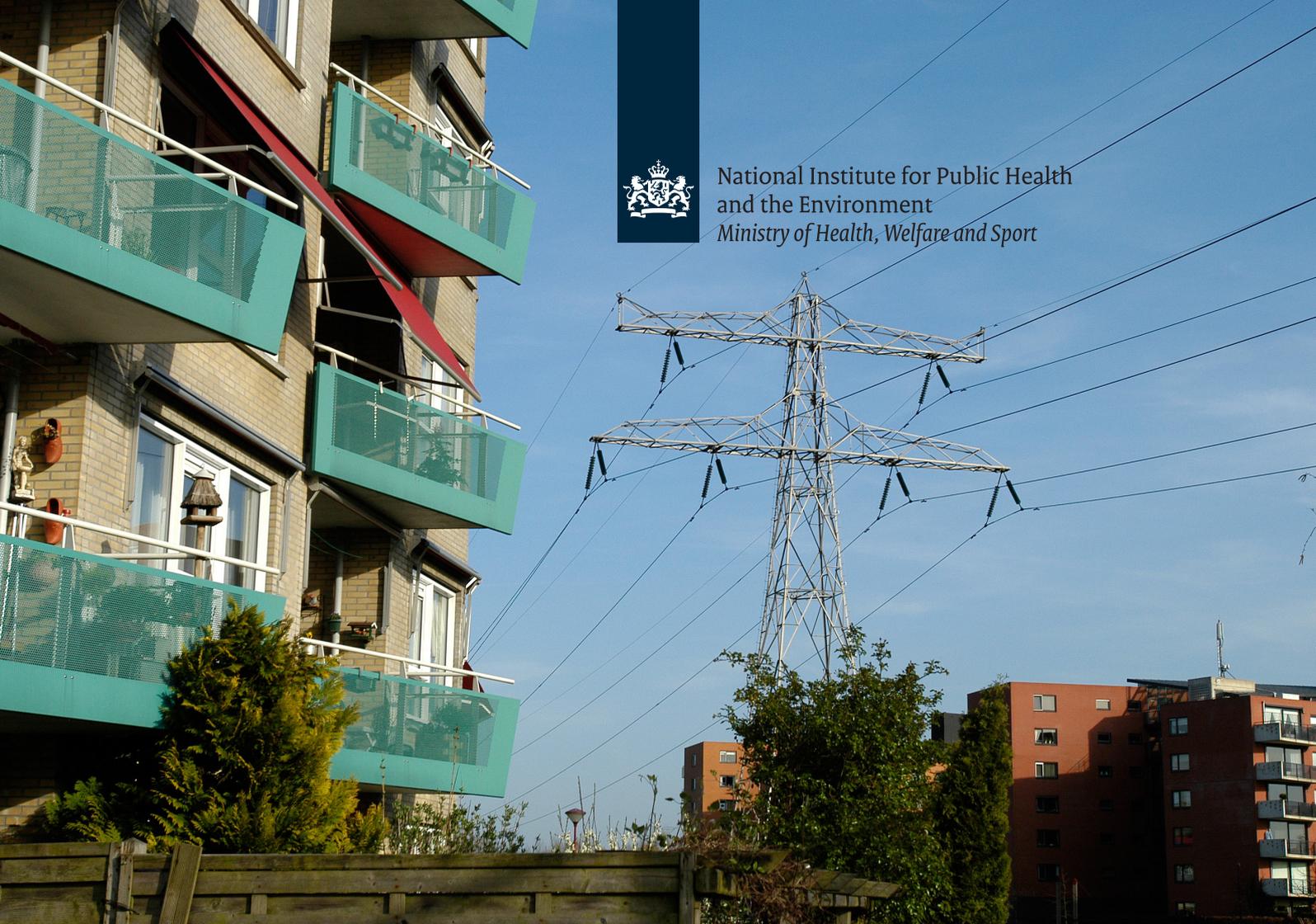




National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport



*National precautionary
policies on magnetic
fields from power lines in
Belgium, France,
Germany, the Netherlands
and the United Kingdom*



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Synopsis

National precautionary policies on magnetic fields from power lines in Belgium, France, Germany, the Netherlands and the United Kingdom

Scientific research points to a possibly increased risk of childhood leukaemia in children who live near overhead power lines. Because of statistical uncertainties and the fact that the disease mechanism is not known, it is not clear whether the magnetic fields of the power lines are the cause. Out of precaution, the Netherlands and several other European countries have developed policies several years ago that aim to reduce the exposure to magnetic fields from new power lines. Different countries deal in different ways with the uncertainties in the available knowledge and strike a different balance between scientific evidence and social, economic and political arguments.

These are the findings of an investigation by the National Institute of Public Health and the Environment (RIVM). The report clarifies the policy in the Netherlands on magnetic fields from power lines and compares it with the policies in four nearby countries (Belgium, France, Germany and the United Kingdom).

These countries differ in the applied limits and in the locations and types of electricity infrastructure to which the policy applies. For example, the policy in the United Kingdom is the most restrained and is aimed at informing the public and changing the connectivity (phasing) of power lines, for example in power stations, which weakens the magnetic field. Further measures are not deemed proportional to the possible risk. Germany applies a policy that aims to minimise magnetic fields from a broader range of electricity infrastructure, for example also for switch stations and the overhead wires of railways.

Keywords: magnetic fields; power lines; potential health effects; policy; practices in other countries

Publiekssamenvatting

Nationaal voorzorgsbeleid over magnetische velden van hoogspanningslijnen in België, Frankrijk, Duitsland, Nederland en het Verenigd Koninkrijk

Wetenschappelijk onderzoek wijst op een mogelijk verhoogd risico op leukemie bij kinderen die in de buurt van bovengrondse hoogspanningslijnen wonen. Door statistische onzekerheden en het onbekende ziektemechanisme is het niet duidelijk of de magnetische velden van de hoogspanningslijnen daar de oorzaak van zijn. Uit voorzorg hebben Nederland en enkele andere Europese landen enkele jaren geleden beleid opgezet om de blootstelling aan de magnetische velden van nieuwe hoogspanningslijnen te beperken. Landen blijken verschillend om te gaan met de onzekerheden in de beschikbare kennis en maken voor hun beleid andere afwegingen tussen de wetenschappelijke bewijslast en sociale, economische en politieke argumenten.

Dit blijkt uit onderzoek van het RIVM. Hierin is het Nederlandse beleid over magneetvelden van hoogspanningslijnen verduidelijkt en vergeleken met het beleid in vier omliggende landen (België, Duitsland, Frankrijk, Verenigd Koninkrijk).

De landen verschillen in de gebruikte limieten en op welke locaties en welk type elektriciteitsvoorzieningen het beleid van toepassing is. Het Verenigd Koninkrijk is bijvoorbeeld het meest terughoudend in beleid en richt zich op publieksvoorlichting en op aanpassingen in de aansluitingpunten van de draden van de hoogspanningslijnen, bijvoorbeeld in de centrale, waardoor het magneetveld zwakker wordt. Verdergaande maatregelen vinden zij niet in verhouding staan tot het mogelijke risico. Duitsland hanteert een beleid dat in bredere zin is ingestoken op het minimaliseren van magnetische velden, dus ook voor bijvoorbeeld transformatorstations en bovenleidingen van treinen.

Kernwoorden: magnetische velden; hoogspanningslijnen; mogelijke gezondheidseffecten; beleid; praktijk in andere landen

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Summary

Power frequency electric and magnetic fields (EMF) are generated in the production, transport, distribution and use of electricity. Epidemiological research has found a statistical relationship between the strength of power frequency magnetic fields near overhead power lines and the risk of leukaemia in children. Based on pooled analyses of the data from individual epidemiological studies, a statistically significant increased risk of childhood leukaemia is associated with long-term exposure to power frequency magnetic fields with a magnetic flux density greater than 0.3 or 0.4 microtesla. It cannot be excluded that the association is (partially) due to statistical bias or confounding and no generally accepted biophysical mechanisms have been identified for the hypothesis that power frequency magnetic fields cause or promote cancer. Nevertheless, some countries have implemented precautionary policies to limit the exposure of children to magnetic fields from overhead power lines or other electricity infrastructure.

This report aims to compare the precautionary policies developed by five European countries that strike a different balance between the scientific evidence for risk and precautionary preventive measures, based on differences in their political, social and economic cultures: Belgium, France, Germany, the Netherlands and the United Kingdom (UK). A regularly updated RIVM database of international EMF policies was used as a starting point. In addition, a literature search was conducted for relevant research papers and reviews in PubMed and Scopus, and searches were performed in Google and Open Grey with search terms related to low frequency magnetic fields, power lines and policy. National experts at the regulators and grid operators in each country then checked a summary text and their comments were used to correct and extend the draft report. The final draft report underwent peer review by two scientists within RIVM who were not involved in the project. This summary section concentrates on precautionary elements in national and regional policy. More details on other EMF policies and legislation can be found in the chapters on each country and in the Discussion chapter.

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. In addition, an indoor environment decree requires those responsible for building or managing homes and public buildings to keep exposure to low frequency magnetic fields below 10 microtesla and advises them to strive for a 'quality aim' of 0.2 microtesla. In Brussels, 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.

In 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. There is no instruction to avoid creating new or modifying existing electricity infrastructure leading to magnetic fields stronger than 1 microtesla near existing 'sensitive locations'. However, the grid operator usually tries to avoid as much as possible the creation of new electricity infrastructure near sensitive locations when planning a new grid development.

In 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 applies only to locations where there are 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 and negative effects on the environment, well-being and occupational safety. Some regions within Germany have applied additional restrictions on new power lines in regional spatial planning legislation, such as minimum distances to places where people may stay or a quality aim of 0.3 microtesla.

In the Netherlands, a ministerial recommendation advises local authorities and grid companies to avoid as far as reasonably possible creating new situations with long-term exposure of children in areas around overhead high-voltage overhead 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 high-voltage overhead power lines, or in the event of changes to existing plans or existing high-voltage overhead power lines. The policy recommendation applies only to overhead power lines, not to other sources of power frequency magnetic fields, for which the epidemiological association with childhood leukaemia has not been demonstrated.

In the UK, in response to the conclusions of a national stakeholders' dialogue, the government stated that it supports the implementation of low-cost options such as optimal phasing to reduce the magnetic field of overhead power lines. The UK government 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 and has no plans to implement them.

In conclusion, based on differences in the balance between the epidemiological evidence and social, economical and political arguments, the countries studied in this report differ in their legal and advisory limits on the strength of the magnetic field, in the definition of 'sensitive locations' and in the type of electricity infrastructure to which it applies. Where precautionary policy is limited to power lines, the arguments tend

to focus on the possibly increased risk of childhood leukaemia. Where the precautionary policy is applied to a broader range of electrical facilities, a more general argument is made to keep fields as low as reasonably possible in the light of scientific uncertainty.

1 Introduction

1.1 Scientific context

Power frequency electric and magnetic fields (EMF) are generated in the production, transport, distribution and use of electricity. The frequency of alternating current and the resulting EMF in the European Union is 50 hertz. In 1999, the Council of the European Union published a recommendation on the limitation of exposure of the general public to EMF (0 hertz to 300 gigahertz) (Council of the European Union, 1999). It contains basic restrictions for the current density induced in the body by EMF and reference levels for the strength of EMF outside the body. The reference level in the EU recommendation for 50 hertz magnetic fields is 100 microtesla. The limits in the EU recommendation are derived from the 1998 Guidelines for limiting exposure to time-varying EMF of the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998). ICNIRP issued new guidelines for EMF with frequencies between 1 hertz and 100 kilohertz in 2010 (ICNIRP, 2010), but these have not yet led to a revision of the EU recommendation. The limits for low frequency fields (1 hertz to 100 kilohertz) are set to prevent scientifically established sensory and health effects mediated by electrical stimulation of sensory organs, nerves and muscles in the body.

Epidemiological research has found a statistical relationship between the strength of power frequency magnetic fields near overhead power lines and the risk of leukaemia in children. Two pooled analyses of the data from individual epidemiological studies published before the year 2000 showed a statistically significant increased risk of childhood leukaemia for long-term exposure to power frequency magnetic fields with a magnetic flux density greater than 0.3 or 0.4 microtesla (Ahlbom et al., 2000; Greenland et al., 2000). In 2002, the International Agency for Research on Cancer (IARC) classified extremely low frequency magnetic fields as possibly carcinogenic to humans (Group 2B). This conclusion was based on the limited evidence in humans for carcinogenicity in relation to childhood leukaemia, where chance, confounding and selection bias could not be ruled out with reasonable confidence as an alternative explanation for the association (IARC, 2002; Schüz, 2007). The association was weaker and not statistically significant in a pooled analysis of individual epidemiological studies published between 2000 and 2010, but these studies were heterogeneous, most of them were relatively small and they lacked methodological improvements on the preceding studies (Kheifets et al., 2010a). On the other hand, the association was found to be reasonably consistent in different countries with different study designs, methods of exposure assessment and systems of power transmission and distribution. This makes it unlikely that it is due to chance, but bias or confounding cannot be excluded (Schüz, 2011).

Leukaemia is the most common form of malignant cancer in children younger than 15 years. Incidence rates in developed countries are typically around 5 per 100,000 children per year (Schüz, 2007). On the assumption that the associations seen in these epidemiological studies were causal, the annual number of new cases of childhood leukaemia

attributable to power frequency EMF in the 27 Member States of the European Union in 2013 (before the accession of Croatia) was estimated to be between 50 and 60, or 2% of the total number of new cases per year (Grellier et al., 2014). Worldwide, estimates for the fraction of yearly cases of childhood leukaemia attributable to power frequency magnetic fields ranges from less than 1% to 4% (Kheifets et al., 2006). However, to date, no generally accepted biophysical mechanisms have been identified for a hypothesised cancer-causing or cancer-promoting effect of power frequency magnetic fields. Animal studies have provided only limited support for such an effect (Lagroye et al., 2011). The existing epidemiological literature on residential exposure to electric (as opposed to magnetic) fields from electricity facilities and household appliances indicates that they are not associated with adverse health effects (Kheifets et al., 2010b).

1.2 Precautionary policy in the EU

Based on the limited evidence that power frequency magnetic fields may possibly cause childhood leukaemia, some countries have opted to take different degrees of precautionary measures to reduce the exposure of children. There is no generally accepted definition of a 'precautionary principle', but the core idea is that decision-makers should act to protect the environment and public health before there is scientific certainty about a cause or mechanism of damage. It is usually applied with some consideration for the balance of risk, benefits and financial costs (proportionality).

In the European Union (EU), precautionary policy first emerged in Germany, where political culture in the late 1980s favoured the idea that the state should seek to avoid environmental damage by careful forward planning. It was applied in the introduction of measures to reduce emerging environmental problems such as acid rain, global warming and North Sea pollution. A similar transition from reactive to proactive environmental management was subsequently made in the EU as a whole (Jordan and O'Riordan, 1999).

The 1991 Treaty on European Union sets out the precautionary principle as a guiding aim: 'Community policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Community. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay'. However, the treaty also sets out a number of restraints: 'In preparing its policy on the environment, the Community shall take account of: available scientific and technical data; environmental conditions in the various regions of the Community; the potential benefits and costs of action or lack of action; the economic and social development of the Community as a whole and the balanced development of its regions' (European Heads of State, 2006).

The European Commission further clarified its interpretation of the precautionary principle in a guidance communication (Commission of the European Communities, 2000). Although the 1991 Treaty mentions the precautionary principle only in the context of protection of the

environment, the Commission broadens its scope to potentially dangerous effects on the environment, human, animal or plant health. It states that the precautionary principle should be considered within a structured approach to risk analysis including risk assessment, risk management and risk communication. It can be applied when potentially dangerous effects of an agent have been identified, but scientific evaluation does not allow the risk to be determined with sufficient certainty. The decision process should be transparent and involve all interested parties as early as possible and to the extent that this is reasonably possible. Where action is necessary, the measures should be proportional to the chosen protection level, non-discriminatory, consistent with earlier measures, based on examination of the potential benefits and costs of action, capable of assigning responsibility for producing additional scientific evidence and subject to review. After scientific evaluation of the risk and the degree of uncertainty, judging what is an 'acceptable' level of risk for society is a political responsibility. The outcome of the process may span the entire range from not acting, through a research project or recommendation, up to a legally binding measure (Commission of the European Communities, 2000). Although it falls within the range of options described in the European Commission's view of the precautionary principle, taking steps to reduce exposure when they carry only modest costs is sometimes called 'prudent avoidance' (Kheifets et al., 2000; WHO, 2000).

1.3 Aims and methods

The present report compares the precautionary policies on magnetic fields from power lines developed by five Western European countries. Each of these countries strikes a different balance between the scientific evidence for risk and precautionary preventive measures, based on differences in their political, social and economic cultures. The aims are to compare the approaches and motivations leading to different power line policies in five neighbouring European countries and to clarify power line policy in the Netherlands for an international audience.

The association with childhood leukaemia was found for magnetic fields from overhead power lines, not for other sources of low-frequency fields (see Section 1.1). The focus of this report is therefore on policies that are related to magnetic fields from overhead power lines. Other sources of magnetic fields related to electricity infrastructure, such as switch stations, local distribution cables and transformers, are sometimes mentioned if they also form part of the system of legislation or precautionary measures for power frequency magnetic fields. Regulations for electric fields from power lines are mentioned when they are also contained in the regulatory documents of a particular country.

The starting point for the information at the basis of this report was a database of international policies on EMF that RIVM has maintained since 2009 and which is updated yearly. Most of the information in the database derives from the websites of national and international regulatory organisations. In addition, a search was conducted for relevant research papers and reviews in PubMed (<https://www.ncbi.nlm.nih.gov/pubmed/>) and Scopus (<https://www.scopus.com/>). For each country, a Google search was also

conducted with different combinations of search terms related to low frequency magnetic fields, power lines and policy in the official language(s) of that country. A search for grey literature was conducted in Open Grey (<http://www.opengrey.eu/>). Details of the search terms and results can be found in the Appendix. A check was made for any errors or missing information with national experts at the regulators and grid operators in each country. The experts were sent a draft summary of policy and their comments were used to correct and extend the draft report. A list of the experts consulted can be found in the Acknowledgements at the end of this report. The chapters on policies in individual countries are in alphabetical order. The final draft report underwent peer review by two experts within RIVM who were not involved in the project.

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2 Belgium

2.1 Background

A federal ministerial decision in 1988, based on the Electricity law, limited the electric field strength due to installations for transport and distribution of electrical energy (5 kilovolt per metre in residential areas, up to 10 kilovolt per metre in other locations) (Ministerie van Economische Zaken, 1988). The limit in residential areas is identical to the reference level in the EU recommendation. No federal limits have been set for the strength of magnetic fields. In 2009, a judgment of the constitutional court, initiated by a telecom operator, determined that the setting of exposure limits for non-ionising radiation was a matter for the devolved governments of the three Regions: Brussels, Flanders and Wallonia (Grondwettelijk Hof, 2009).

The Superior Health Council advises the federal government and health professionals on public health risks. In 2008, it assessed the scientific evidence for risks of power frequency magnetic fields from electrical installations. Referring to the IARC classification and the precautionary principle, it advised that long-term exposure (not defined) of children younger than 15 years in their usual places of stay (home, care centre, schools) should not exceed 0.4 microtesla. In practical terms, it advised that new power lines should preferably be laid underground and that the location of new public electrical installations should take account of the distance to places of stay. Indicative distances were given for power lines of different voltages, transformers and electrical devices associated with long-lasting exposure such as electric alarm clocks and heaters (Hoge Gezondheidsraad, 2008). The regional Agency for Healthcare in Flanders has advised that the authorities should strive for a situation in which children younger than 15 years do not stay in magnetic fields stronger than 0.2 microtesla for long periods of time (Agentschap Zorg & Gezondheid, 2012). This advice was presumably based on the Flemish 'quality aim' in Flemish environmental legislation (see Section 2.2), although this was not specified.

The Flemish government organised a consultation project on the health risks of power frequency fields from electrical installations such as power lines, which focused on the risk for childhood leukaemia and involved scientific experts and stakeholders. The participants concluded that there was sufficient reason for concern and precaution. They advised new policies which make a distinction between new and existing situations and use a limit or 'quality aim' for magnetic field exposure of children. Suggested measures were undergrounding, with due reference to costs and other benefits, technical measures to reduce the field strength and placing transformer cabins outside apartment blocks (Goorden et al., 2011).

2.2 Present policy

In the region Flanders, the indoor environment decree (Binnenmilieubesluit) contains a 'quality standard' for power frequency fields inside homes and public buildings, which sets an exposure limit

value of 10 microtesla and a 'quality aim' of 0.2 microtesla to protect the general population against possible risks of long-term exposure. Those responsible for building or managing the premises are advised to achieve or maintain the quality aim as far as possible. The motivation for the decree specifically cites the precautionary principle and states that the measures are weighed against the probability and seriousness of suspected effects, the size of the exposed population and the expected societal impact of effects and measures (Vlaamse Regering, 2004). Following the 2011 consultation project, the Flemish Ministers for the Environment, Health and Spatial Planning specified a policy with regard to possible risks of magnetic fields from power lines. It states that the spanning of existing sensitive locations (schools and childcare centres) by new power lines should be avoided and the spanning of homes kept to a minimum; new sensitive locations should not be placed in the magnetic field zone (long lasting exposure over one year greater than 0.4 microtesla with year-averaged load) of existing power lines; where new situations with homes spanned by the line cannot be avoided, home owners can be bought out or financially compensated for loss of value (Vlaamse Regering, 2012; Vlaams Parlement, 2013). These principles are also referred to in a government guideline on environmental factors in childcare facilities (Vlaamse Overheid, 2016).

The Brussels region applies a limit of 100 microtesla for the magnetic flux density outside local transformers (Brusselse Hoofdstedelijke Regering, 2000), which is identical to the reference level in the EU recommendation. Although no legislation with precautionary limits has been adopted, the Minister for Environment, Energy and City Renewal has advised the Regional Department of Environment and Energy, when granting environmental permits for new fixed transformers with a power greater than 250 kilovolt-ampere, to limit the magnetic flux density to a 24-hour average of 0.4 microtesla near newly installed transformers in places where children under the age of 15 may stay. If this is not possible for technical or economic reasons, the owner should minimise the field as far as reasonably possible and ensure that it does not exceed 10 microtesla (Huytbroeck, 2013). Magnetic fields from power lines are less of an issue in the Brussels region, since these are generally underground (HoogspanningsNet, 2016). Nevertheless, a proposal for a new decree was brought before the regional parliament in 2016 which would have expanded the limit of 10 microtesla and quality aim of 0.4 microtesla to all power lines and cables (Brussels Hoofdstedelijk Parlement, 2016a). This proposal was rejected (Brussels Hoofdstedelijk Parlement, 2016b).

In the region Wallonia, the electric and magnetic field generated by transformers with a nominal power of 1500 kilovolt-ampere or greater in zones with permanent human habitation is limited to the reference levels in the EU recommendation (Gouvernement Wallon, 2005). There are no precautionary policies for power-frequency magnetic or electric fields (ISSeP, 2014).

2.3 Practical and administrative aspects

Elia is the operator of the Belgian high-voltage grid from 30 to 380 kilovolt. The grid up to 70 kilovolt is defined as the local transmission grid under the competence of the Regions. The grid above 70 kilovolt is a

federal competence. As a result, there are four regulators: one federal and three regional. The authorisation of new high-voltage installations (substations, transformers, lines and cables) is the sole competence of the regions and therefore only the regional policies regarding magnetic fields apply. The locations of new large infrastructure (overhead lines, cross-country cable connections and the affiliated substations) have to be determined in a spatial plan and are subject to an environmental impact assessment at plan and project level. This assessment includes the participation and consultation of the different stakeholders (Elia, 2015). The evaluation of magnetic field exposure is an important factor in the decision on the final solution and location. Recent guidelines on health aspects in the environmental impact assessment ask for an estimate of the potential increase of the number of cases of childhood leukaemia on the basis of the total number of children in the 0.4 microtesla zone (Departement Leefmilieu, Natuur en Energie, 2016). Interested parties can legally challenge the decision at the Council of State, whose judgment is final. On the other hand smaller high-voltage infrastructure projects (cables under public roads, extension of existing substations) are not subject to an environmental impact assessment and in some cases do not even require a building permit.

The Flemish Institute for Technological Research (VITO) has developed a calculation method for determining the extent of zones where the magnetic flux density exceeds 0.4 microtesla near power lines, transformer stations and local transformer cabins. Since power lines are associated with more than 95% of the exposure locations with a magnetic flux density greater than 0.4 microtesla, policies on power lines will affect the majority of exposures of the general public. Calculations use a current load of 50% (van Esch et al., 2014).

2.4 Future plans

The Flemish indoor environment decree, including provisions for low frequency magnetic fields, is under revision. In the region Brussels, the regional government and grid operator Elia are developing a set of best practices on configuration and distance from dwellings with the aim of limiting EMF of 150 kilovolt cables. It is expected that this will be adopted by all parties involved in new electricity connections (du Bus, 2016). For the time being this voluntary agreement between Elia and the Brussels government is not yet applied because the mayors have not yet approved it. As cables are generally placed under local roads, they fall within the competence of the local authorities.

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3 France

3.1 Background

The Law on urban renewal gave regional authorities (préfectures) the power to forbid the new construction or remodelling of houses and public buildings near power lines and pylons with a voltage of 130 kilovolt or higher (République Française, 2000). Minimum distances (at most 30 to 40 metre, depending on the voltage) were specified in a subsequent decree (République Française, 2004). However, this law was not related to possible health risks but to more general, unspecified spatial planning considerations (AFSSET, 2010a).

The National Health and Security Agency AFSSET (now amalgamated into ANSES) published a review of possible health effects of extremely low frequency fields in 2010. It concluded that no change in exposure limits was necessary but, as a precautionary approach, measures should be taken to avoid increasing the number of children and pregnant women exposed to magnetic fields near high-voltage power lines and to reduce exposure. It was suggested that this could take the form of an exclusion zone with a minimum distance of 100 metre from very-high-voltage power lines where new buildings accessible to the public, such as hospitals and schools, could not be built (AFSSET, 2010a). According to the accompanying background report (AFSSET, 2010b), the maximum magnetic flux density at a distance of 100 m can vary from 0.1 microtesla (90 kilovolt overhead power line) to 1.2 microtesla (400 kilovolt overhead power line).

In the same year, a report by the Parliamentary Office for Evaluation of Scientific and Technological Options, following consultation and round table discussions with stakeholders (scientists, pressure groups, politicians and network operators), recommended that the government investigate whether it was possible not to increase the number of children younger than 6 years (the period when the majority of childhood leukaemias occur) exposed for several hours per day or longer to year-averaged fields stronger than 0.4 microtesla at reasonable cost (Raoul, 2010). Referring to policy in the Netherlands, the Environment and Economic Affairs ministries then commissioned an expert report that investigated the practical possibilities for implementing the recommendations by AFSSET and the Parliamentary Office and put them in the context of precautionary policies in other countries. This report concluded that a fixed distance was incompatible with scientific evidence and technical variability. Based on a balance between epidemiological evidence, technical possibilities and economic viability it advised a limit of 1 microtesla for new situations, following the example of Switzerland. It gave three legal options to implement this policy through local spatial planning procedures: the creation of an exclusion zone ('right-of-way') following the definition in the Electricity Law where construction is prohibited; a recommendation to mayors to avoid new sensitive locations in a 'precautionary zone'; the establishment of an obligation by the grid operator to provide the authorities with information on the risk

of extremely low frequency magnetic fields to 'sensitive persons' (children and pregnant women) (Follenfant and Leteurtois, 2010).

3.2 Present policy

In France the Decree on the Technical Conditions for the Distribution of Energy makes the reference levels in the EU recommendation binding for extremely low frequency fields generated by new or modified installations in places accessible to the public (République Française, 2001). Recently, following the recommendations of the expert report (Follenfant and Leteurtois, 2010), the Ministry of Ecology, Sustainable Development and Energy issued a non-binding instruction to the préfetures to avoid as far as possible the creation of new sensitive locations (hospitals, maternity wards and childcare facilities such as primary schools and crèches) near power lines, cables, transformers and bus bars where children are exposed to a magnetic field stronger than 1 microtesla (Ministère de l'Écologie, 2013). There is no instruction to avoid creating new or modifying existing electricity infrastructure which produces magnetic fields stronger than 1 microtesla near existing sensitive locations. The decision to allow new electricity infrastructure near existing sensitive locations therefore seems to be a matter of judgement for regional governments. Nevertheless, when planning a new grid development, the grid operator manages the project so as to minimise its environmental impact. This includes avoiding as far as possible the creation of new electricity infrastructure neighbouring sensitive locations.

3.3 Practical and administrative aspects

The Electricity Code requires that local stakeholders are informed of plans for the construction of new public utilities such as power lines. The regional government decides if the plan can go ahead (République Française, 2014). The grid operator informs the préfet (the state's representative in a département or region) and the mayors of the municipalities in question of the plans and provides a technical dossier. The préfet then organises a public consultation process and makes the final decision on siting (République Française, 2011). For major electricity infrastructure projects (typically involving 400 kilovolt power lines), the main administrative decisions are taken at the national level by the Ministry of Ecology and Energy. The grid operator (Réseau de transport d'électricité, RTE) is a project manager in these processes. The regional health agencies and environment authorities examine the impact study provided by RTE.

Since 2009, a voluntary agreement with the Association of Mayors in France commits RTE to respond to any information request about EMF generated by the high-voltage network. Citizens have the possibility to submit an information request through their mayor. In practice, once a request is received, RTE either proposes an on-site visit by an employee, who will perform measurements and answer any questions regarding EMF and the network, or, if independent measurements are preferred, mandates a laboratory, in which case the measurement report is sent directly to the mayor. Since 2010, RTE has received about 30 requests per year, and about half of them have asked for independent measurements. All these measurements (about 250 at the

end of 2016) are published on RTE's information website dedicated to EMF (RTE, 2010; <http://www.clefsdeschamps.info/Carte-de-mesures>).

In 2011, a national decree (République Française, 2011) established an EMF Control and Survey Plan whereby the grid operator is committed to providing information on the EMF levels in urbanised areas crossed by power lines (overhead and underground). These measurements must be made by accredited laboratories following a national standard (UTE, 2010) and then extrapolated by RTE in order to assess the maximum EMF levels corresponding to the maximum load of the line under normal working conditions. About 5000 measurements were planned between 2013 and 2017. Measurement results and extrapolations are given to ANSES every year to be made public. A dedicated website has been developed for that purpose (<https://www.cem-mesures.fr/>).

3.4 Future plans

The EMF Control and Survey Plan will be finished for existing lines by the end of 2017. After 2017, measurements will focus on new lines (within a year after powering-up) or situations where changes in the local environment may lead to an increase in the exposure of people to the magnetic field, with a 10-year control cycle (République Française, 2011). No new precautionary policies related to low frequency EMF are currently planned.

3.5 References

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4 Germany

4.1 Background

At the beginning of 1997, the first version of the Ordinance on electromagnetic fields, the 26th federal Ordinance under the Law on environmental pollution (Bundesimmissionsschutzgesetz) came into force. For extremely low frequency fields, this regulation sets legal limits only for electric field strength and magnetic flux density with frequencies of 16.7 and 50 hertz. These limits are identical to the reference levels in the 1998 ICNIRP guidelines and 1999 EU recommendation (for 50 hertz: 5000 volt per metre and 100 microtesla). The electric field strength and magnetic flux density could exceed the limits by a maximum of 100% for short periods (at most 5% of the day). Electric field exposures could exceed the limits by a maximum of 100% near buildings. The electric field strength and magnetic flux density from new or substantially modified low frequency facilities could not exceed the limits near homes, hospitals, schools, childcare facilities, playgrounds or similar establishments (Bundesministerium der Justiz, 1996). A definition of 'near' for various low frequency facilities was given in subsequent guidelines on the implementation of the Ordinance (Länderausschuss für Immissionsschutz, 2004).

Spatial planning law in Germany is a matter for the government of the regions or Länder. From the mid 1990s, regional spatial planning decrees or recommendations on minimal distances between industrial and residential areas have set minimal distances between new housing and power lines of up to 50 metre, depending on voltage (see for example: Land Brandenburg, 1995; Land Nordrhein-Westfalen, 2007). These distances were based on a compromise between the ICNIRP-based reference levels in the federal environmental pollution law, precautionary policy and practical considerations. One basis for the determination of distance was the 1997 recommendations by the German radiation protection commission (Strahlenschutzkommission). These stated that, if precautionary reductions in reference levels were to be considered, they should not lead to reference levels for instantaneous exposure lower than 10% of the ICNIRP reference level for magnetic flux density or 33% of the reference level for electric field strength. These percentages were based on the lowest field strengths that could disturb active implanted medical devices or elevate the internal electric field strength above physiological levels (Strahlenschutzkommission, 1997). Some of these distance-based regional planning restrictions for building near power lines were later withdrawn (Land Brandenburg, 2014) but others still appeared to be valid in 2016 (Land Nordrhein-Westfalen, 2007). Where minimum distances to housing prevent the erection of overhead power lines, some regions have enabled partial undergrounding of technically and economically viable sections (Land Niedersachsen, 2007).

4.2 Present policy

The most recent version of the Ordinance on electromagnetic fields limits the exposure of members of the public to static magnetic fields and EMF in the entire frequency range from 1 hertz to 300 gigahertz

(Bundesministerium der Justiz, 2013). For electricity grids with alternating current, it applies to fixed installations for transformation and transport of electricity at a voltage of 1000 volt or higher in places 'not exclusively meant for temporary stay of people' (Bundesregierung, 2013). For electricity grids with direct current, it applies to fixed installations for the transformation, conversion and transport of electricity at a voltage of 2000 volt or higher in places 'meant for long-term or temporary stay of people'. For low frequency fields, the mandatory limits for electric and magnetic fields at the highest possible operational load are identical to the reference levels in the 2010 ICNIRP low frequency guidelines, with the exception of the limit for magnetic fields with a frequency of 50 hertz. This is set at 100 microtesla, identical to the reference level in the 1999 EU recommendation and the 1998 ICNIRP guidelines, but half the reference level in the 2010 ICNIRP guidelines. The motivation was that the protection level at 50 Hz should not be relaxed. Only for facilities built before the entry date of the 2013 Regulation may short-lasting (at most 5% of the day) electric and magnetic field exposures exceed the limits by a maximum of 100%. Electric field exposures may exceed the limits by a maximum of 100% in small areas outside buildings. For static magnetic fields from direct current facilities, the limit at the highest possible current load is set at 500 microtesla, approximately 1% of the basic restriction in the EU recommendation and 0.1% of the basic restriction in the 2009 ICNIRP guidelines. This low value was chosen to prevent harmful 'indirect effects' on cardiac pacemakers (Länder-Arbeitsgemeinschaft für Immissionsschutz, 2014).

In addition to the fixed limits, based on scientifically validated mechanisms involving electrical stimulation, the Regulation contains precautionary obligations. These were based on a possibly increased risk of childhood leukaemia as well as on a more general strategy to keep exposure as low as reasonably possible. For new or substantially modified low frequency facilities near homes, hospitals, schools, childcare facilities, playgrounds or similar establishments, the limits for electric and magnetic fields may not be exceeded, not even for short periods. When creating or substantially modifying direct current and alternating current facilities (installations for transforming and conducting electricity with voltages greater than 1 kilovolt), all possibilities to minimise electric, magnetic and electromagnetic fields should be exhausted according to the technical state of the art. Power lines for alternating current with a frequency of 50 hertz and a voltage of 220 kilovolt or higher that are going to be built along a newly planned route may not span buildings meant for long-term stay of people (Bundesministerium der Justiz, 2013).

The 2013 Ordinance was followed by more detailed instructions on its practical application in a regulation (Verwaltungsvorschrift) for its implementation (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 2016). The obligation to minimise the electric and magnetic field applies in those areas surrounding new electricity facilities where the magnetic flux density significantly exceeds the natural and average human-generated magnetic flux density. The obligation to minimise the field only applies to those locations within such areas where homes, hospitals, schools, childcare facilities, playgrounds or similar

establishments are located or any other location not exclusively meant for the temporary stay of people. Minimisation measures need to be proportional with regard to cost, functionality and negative effects on the environment, well-being and occupational safety. Possible minimising measures are: increasing the vertical distance to conductors, minimising distances between conductors, optimising pylon head geometry and optimising the phase order of currents in adjacent cables. Consideration of alternative locations for towers or lines is not required (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 2016). An interpretation of the distances from various sources of low frequency fields within which the minimisation obligation applies is given in interregional guidelines (Länder-Arbeitsgemeinschaft für Immissionsschutz, 2014).

The Law on extension of power lines (Energieleitungsausbaugesetz) applies to new lines of 380 kilovolt and higher and creates the conditions for integration of electricity from renewable energy sources, connection of new power stations, removal of grid bottlenecks and interoperability of electricity grids in the EU. The text does not specifically mention magnetic fields or health risks but seems to be aimed more generally at improved acceptability by the population. It provides context and specifies how undergrounding should be executed. It designates specific projects as pilot projects to test undergrounding and gives general rules for when the authorities can demand that power lines in such a pilot project should be laid underground on segments where this is technically and economically efficient. This applies to lines closer than 400 metre to homes in built-up areas, lines closer than 200 metre to homes outside built-up areas, and areas where undergrounding would prevent conflicts with nature conservation legislation or where the line crosses a federal waterway broader than 300 metre. The costs for undergrounding can be added to grid operating charges in energy bills (Bundesministerium der Justiz, 2015).

Some regions have applied a more general restriction on new power lines in regional spatial planning legislation. Niedersachsen's spatial development plan states that there should be a minimum distance of 400 metre between new power lines and homes, schools, childcare facilities, hospitals or nursing homes in built-up areas, and undergrounding should also be considered (Land Niedersachsen, 2012). In other regions, local policy is more restrictive than federal policy, especially when establishing new housing areas. For example, in Bremen a senatorial recommendation applicable to new building plans for housing areas seeks to minimise the magnetic field in new situations in all places not exclusively meant for the temporary stay of children. In these locations, the local authorities should strive for an average magnetic flux density over 24 hours of 0.3 microtesla as a quality aim. The recommendation applies to all fixed facilities for energy supply (power lines, transformers and electric rail facilities) (Freie Hansestadt Bremen, 2016).

4.3 Practical and administrative aspects

High-voltage power lines in Germany have a voltage of 220 or 380 kilovolt for long distance transport and 20 to 110 kilovolt for distribution. Although

the actual average load is usually 50%, calculations for planning procedures use a load of 100% (50Hertz, 2015; Bundesministerium für Wirtschaft und Energie, 2016). For new power lines or modification of power lines of 110 kilovolt or higher, spatial planning procedures typically have to be executed by the regional authorities, which must weigh public and private interests (Bundesministerium der Justiz, 2005). For new power lines of 220 kilovolt or higher with a length greater than 15 kilometre, an environmental impact assessment is mandatory (and for all other cases a preliminary environmental impact assessment is mandatory), in which the provisions of environmental legislation, including those on EMF, must be satisfied (Bundesministerium der Justiz, 2010).

In recent years, the planning of new power lines has been streamlined on a national level. Scenarios for the general needs for grid extensions are drawn up by the grid operators in a grid development plan that includes environmental impacts (Netzentwicklungsplan). This plan has to be confirmed by the national grid agency (Bundesnetzagentur) and can be commented on by society (civilians, companies or authorities). The federal government then draws up a national plan of necessary connections (Bundesbedarfsplan), which is implemented in detailed spatial plans (Bundesfachplanungsverfahren). These minimise the impact on humans and the environment through discussions held in a conference session and individual hearings with stakeholders. Local stakeholders can comment on the plans. The final route for projects covering more than one region is decided by the national grid agency; for other projects, by the local authorities (Bundesnetzagentur, 2014).

4.4 Future plans

Germany's plans for a shift from fossil fuels and nuclear fission to renewable energy sources (Energiewende) necessitate investment in new power lines, for example from the wind-rich north to the south of the country. Future lines for long-distance transport of electricity, such as the SuedLink, will increasingly use direct current, which generates a static magnetic field rather than a 50 hertz alternating field. These lines will normally be laid underground (Bundesministerium für Wirtschaft und Energie, 2016).

4.5 References

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5 Netherlands

5.1 Background

After assessing the epidemiological evidence in the year 2000, the Health Council of the Netherlands – an advisory body to the Dutch government – concluded that there was a reasonably consistent statistical association between living near overhead power lines and an increase in the incidence of leukaemia in children. It also stated that a causal relationship between childhood leukaemia and power frequency fields could not be proven and that experimental research had not identified any plausible biological mechanism. The Health Council concluded that there was no reason to recommend taking measures to limit residence near overhead power lines (Health Council of the Netherlands, 2000). An RIVM report published in 2001 concluded that if the magnetic field were assumed to be the cause, the risk of leukaemia in children younger than 15 years would be increased at magnetic flux densities higher than 0.2 to 0.5 microtesla. The calculated number of extra cases of childhood leukaemia in the Netherlands would then be between 0.2 and 1 per year (van der Plas et al., 2001).

Because of public concern and the inconclusive scientific evidence, the Dutch government indicated, in the Fourth National Environmental Policy Plan (NMP4), that the present evidence provided sufficient reason for further research and for taking appropriate precautionary measures in relation to social costs and benefits (VROM, 2001). Subsequent assessments by RIVM and KEMA gave a more accurate estimate of the number of homes affected and the costs and benefits of various mitigation strategies (Kelfkens et al., 2002; KEMA 2002; Pruppers, 2003). This led to a revised conclusion that, if the association was assumed to be causal, up to 0.5 extra cases of childhood leukaemia per year would be attributable to magnetic field exposure from overhead power lines (Pruppers, 2003).

The Environment Ministry stated a policy aim to avoid as much as possible any new situations where children are exposed to magnetic fields from overhead power lines. It left the exact method and magnetic field strength open for further discussion by the stakeholders (municipalities, provinces, grid operators, housing corporations) (VROM, 2004a). A round table with stakeholders then led to a report on policy alternatives for overhead power lines. Its main conclusions were that there was sufficient support for a new policy to avoid new situations in which 'sensitive' locations (homes, schools, childcare facilities) would be located near power lines; that spatial 'zoning' would be the most effective strategy to achieve this; that a limit for a yearly-average magnetic flux density was accepted as a political choice; that zones with boundaries based on a yearly-average flux density of 0.4 microtesla should be calculated and recorded in an 'atlas' (map repository) and in national and regional spatial plans; and that a simple calculation method was necessary (VROM, 2004b).

5.2 Present policy

In the Netherlands, there are no binding national limits for 50 hertz electric or magnetic fields based on the EU recommendation. The health and safety of members of the general population with regard to electrical appliances is governed in a general way by consumer product legislation, which is partially based on the EU Low Voltage and Machinery directives. There is also no specific environmental legislation for overhead power lines. The construction of new overhead power lines or of housing near existing overhead power lines is regulated by general spatial planning legislation.

In 2005, the State Secretary for the Environment issued an additional recommendation, as a precautionary policy, that when making spatial plans and determining the trajectory of overhead high-voltage power lines, or in the event of changes to existing plans or existing overhead high-voltage power lines, local and regional authorities and grid operators should avoid as much as reasonably possible creating new situations with long-term exposure of children in areas around overhead high-voltage power lines with an annually averaged magnetic flux density greater than 0.4 microtesla (the magnetic field zone) (VROM, 2005).

The recommendation was elaborated on by the Minister for the Environment in a subsequent letter (VROM, 2008). This letter defines the magnetic field zone as the area that extends along both sides of the overhead high-voltage power line and within which the magnetic field is, on average over a year, higher than 0.4 microtesla or could become so in the future. The 'specific zone' is the magnetic field zone calculated according to the Guide drawn up by RIVM (see Kelfkens and Pruppers, 2015 for the latest version). The 'indicative zone' is the magnetic field zone calculated on the basis of a number of conservative estimates as an approximation of the specific zone. 'Children' is defined as people aged between 0 and 15 years. 'Long-term exposure' applies to children who live or spend time in homes (dwellings), schools, kindergartens (crèches) or day care centres, collectively termed 'sensitive designated uses'. 'New situations' refers to new spatial plans, changes in existing spatial plans, new overhead high-voltage power lines and changes to existing overhead high-voltage power lines. The recommendation applies only to new situations because the health effects are unclear and measures applied to existing situations often have substantial social consequences (such as the relocation of dwellings or of overhead high-voltage power lines). New situations offer more options for alternative locations and prevention can be cheaper than redevelopment. For existing situations, the reference level of 100 microtesla in the EU recommendation applies (VROM, 2008). The additional Dutch government policy recommendation applies only to overhead power lines, not to other sources of power frequency magnetic fields such as underground cables, switch stations, transformer cabins or certain railway lines, for which the epidemiological association with childhood leukaemia has not been demonstrated.

In addition to the national policy recommendation some Municipal Public Health Services have issued advice in which they widen the scope to substations and transformer cabins. They advise local government to attempt – against reasonable costs – to reduce the magnetic flux

density as much as possible below 0.4 microtesla in specific local situations where children can stay for a long time near substations and transformer cabins. According to this advice, what is reasonable can be considered in both existing and new situations (LCM, 2006).

5.3 Practical and administrative aspects

When planning a new overhead power line (usually on a national level) or new housing near an existing overhead power line (usually on a municipal level), the authorities must draw up a detailed zoning plan (inpassingsplan or bestemmingsplan). Depending on the length and voltage of the power line, an environmental impact assessment (milieueffectrapportage) can be necessary, which may be preceded by or combined with a strategic environmental assessment (strategische milieubeoordeling). This includes determining the indicative zone or specific zone of the power line's magnetic fields and exploring alternative locations or constructions. One technical option is to reduce magnetic field exposure with specially designed pylons (TenneT, 2010). Those affected, such as local inhabitants or businesses, can file their opinion. This may lead to changes, after which the zoning plan is finalised. Competent authorities on a local or national level need to carefully weigh the advantages and disadvantages of any decision for planning permission for new sensitive locations in the magnetic field zone of overhead power lines. Specific local circumstances such as major societal benefits could lead to a decision to allow sensitive locations in the specific zone. The justification is normally included in the zoning plan. Interested parties (citizens or organisations) who still oppose parts of the zoning plan may seek adjudication by the highest judge in administrative law, the Administrative Jurisdiction Division of the Council of State (Afdeling Bestuursrechtspraak van de Raad van State), whose decision is final (Rijkswaterstaat, 2015).

To operationalise the ministerial recommendation on magnetic fields from power lines, RIVM has developed dedicated webpages (<http://www.rivm.nl/Onderwerpen/H/Hoogspanningslijnen>), a digital map of overhead power lines for visualising indicative zones and a guide for determining specific zones. The guide explains the choices made for calculating the zone, indicates what input data are used for zone calculations and determines how the results of zone calculations are reported. The magnetic flux density near overhead power lines depends on the current, which varies with energy demand and supply. Based on yearly average load and leaving a margin for future increases in electricity use, the calculations usually use a load of 30% of design load for 220 and 380 kilovolt lines and 50% of design load for 50, 110 and 150 kilovolt lines. The guide has been updated several times, most recently in 2015 (Kelfkens and Pruppers, 2015). Since 2009 RIVM has also maintained a list of agencies that use a calculation method that is compatible with the arrangements in its guide and leads to concordant results. Local government can use this list to select a reliable agency to make specific calculations for areas where new development is planned.

5.4 Future plans

An additional policy is being implemented to provide opportunities to remove dwellings directly underneath the conductors of overhead high-voltage power lines. However, it is not linked to the precautionary policy

on new situations near overhead power lines, nor with possible health effects due to living near overhead power lines. Overhead high-voltage power lines in the Netherlands have one of five voltage levels: 380, 220, 150, 110 or 50 kilovolt. Plans for new power lines with a voltage of 220 kilovolt or higher are usually decided on and coordinated by the national government. In a Cabinet decision in 2008, it was established that new power lines of 220 kilovolt or higher would, in principle, be constructed above ground. The lower cost and greater stability of the electricity grid were the main arguments for this (Tweede Kamer der Staten-Generaal, 2008).

Following national discussions on the upgrading of a power line to 380 kilovolt, the Minister for Economic Affairs stated his intent for a new policy to 'relieve citizens from the burdens associated with power lines'. The Minister stressed that living near power lines is not unsafe, but is sometimes associated with sources of annoyance (such as visual impact or crackling noises) (EZ, 2011). His successor developed detailed plans for a programme with a combination of undergrounding and buy-outs. Over a period of 5 years, starting in January 2017, owners of homes that are located directly under the conductors of a 220 to 380 kilovolt power line, under the conductors of a 50, 110 or 150 kilovolt power line outside an inhabited built-up area, or under the conductors of a 110 or 150 kilovolt power line shorter than 1 kilometre within an inhabited built-up area can be bought out at their own request. A home can also be moved or rebuilt elsewhere if this is more cost-efficient. The estimated number of affected homes in the Netherlands is 375 (EZ, 2013; EZ, 2015; EZ 2016).

A new proposal for amending the Electricity Act 1998 aims to make it possible for the national grid operator to underground or relocate parts of existing power lines of 50 kilovolt or higher at the request of local or provincial authorities. Such requests can be made only for trajectories where undergrounding or relocation is cost efficient, as indicated by the Minister for Economic Affairs. This may concern reconstructions that are a cost effective alternative for the buying-out scheme, but also power lines longer than 1 km with a voltage of 50, 100 or 150 kilovolt in inhabited built-up areas qualifying for undergrounding. The legislation is expected to be approved by Parliament in 2017, after which undergrounding and relocation could start. The costs will be shared by local authorities and consumers, the latter via electricity transport tariffs.

In March 2014, the Ministry of Infrastructure and the Environment asked the Health Council of the Netherlands for an update of its scientific evaluation of the association between living near overhead power lines and childhood leukaemia following several publications that found no indications of such an association. The Health Council literature review will look at associations with both distance and magnetic field flux density and is expected to be published in 2017. The government can use this new evaluation to assess whether the present precautionary policy needs to be reconsidered (IenM, 2014).

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6 United Kingdom

6.1 Background

In 2004, the National Radiological Protection Board (NRPB, amalgamated into the Health Protection Agency in 2005, and then into Public Health England in 2013) recommended the adoption of the basic restrictions and reference levels in the ICNIRP guidelines (NRPB, 2004). This did not lead to specific national legislation containing EMF exposure limits for the general public. However, the UK government welcomed the advice and stated that it expected the public exposure guidelines to be implemented in line with the terms of the EU recommendation, taking account of the risks and benefits of action (Department of Health, 2004).

Particularly in view of the possible effects of long-term exposure to power frequency magnetic fields, NRPB also advised the UK government to consider the possible need for further precautionary measures (NRPB, 2004). The Department of Health subsequently organised a Stakeholder Advisory Group on extremely low frequency EMF (SAGE), with representatives from national government departments, regulators, advisory bodies, scientists, professional bodies, industry, local and national campaign groups and individual citizens. Its task was to consider possible precautionary measures under the assumption that EMF cause an increased risk of childhood leukaemia, but not to determine how likely or unlikely it is that the EMF actually cause an increased risk.

The first of the resulting two reports made recommendations with regard to power lines and to wiring and electrical equipment in homes. With regard to power lines, SAGE recommended two low-cost options aimed at reducing exposure. The first was that more information be provided to members of the public about exposures and the actions they could take themselves to reduce exposures if they wished. The second was that electricity companies be encouraged to choose the optimal phasing (usually transposed phasing) for all new lines and to convert existing lines where possible and justifiable. Since these low-cost options were deemed unlikely to result in substantial reductions in exposure, SAGE urged the government to make a clear decision on whether or not to implement one of a list of further options that would result in significant exposure reduction by limiting the number of new homes and schools within certain specified distances of existing power lines and limiting new power lines within the same distances of existing buildings (SAGE, 2007).

In the second report, SAGE made additional recommendations on possibilities to reduce exposure from electricity distribution grids, including low voltage and intermediate voltage circuits and substations (SAGE, 2010). After receiving advice from the Health Protection Agency (Health Protection Agency, 2007; Health Protection Agency, 2010), the government responded to both sets of recommendations and these responses formed the basis for the present policy described below.

6.2 Present policy

UK government policy is that exposure of the public should comply with the ICNIRP (1998) guidelines in terms of the EU recommendation. In line with the EU recommendation, it specifies that the ICNIRP limits will apply to properties where members of the public spend an appreciable proportion of their time, such as residential properties and schools. The electricity industry has agreed to follow this policy (Department of Energy & Climate Change, 2011). The response of the government to the 2007 SAGE report supports the implementation of the low-cost options recommended by SAGE (for example optimal phasing, informing the public). The UK government considers the additional reduction of magnetic field exposure by creating exclusion zones between homes and power lines to be disproportionate in the light of the evidence base on the potential health risks and has no plans to implement them (HM Government, 2009).

It is also the UK government's policy that power lines should not be re-routed or undergrounded solely for the purpose of reducing exposure to EMF. Although there may be circumstances where the costs of undergrounding are justified for a particular development, this is unlikely to be on the basis of EMF. These EMF policies are applied to new power lines by a National Policy Statement (Department of Energy & Climate Change, 2011). Responding to the second SAGE report recommendations and following a response by the Health Protection Agency (Health Protection Agency, 2010), the UK government said that it would explore the possibilities for relevant engineering recommendations to be developed by the Distribution Network Operators (HM Government, 2011). Public Health England has published information on its website to help inform people about exposures and the actions they could take themselves to reduce exposures (Public Health England, 2017).

6.3 Practical and administrative aspects

For new power lines in England and Wales, the applicant (grid operator) applies for consent to the Secretary of State for Energy and Climate Change. However, power lines of 132 kilovolt and higher and longer than 2 kilometre are considered Nationally Significant Infrastructure Projects and are considered by the Planning Inspectorate. The applicant then informs relevant local planning authorities or other statutory consultees of its plans to construct a new power line. The applicant organises a consultation process in which views are obtained from the local community and relevant organisations for environmental and heritage protection. For applications directly to the Secretary of State, if the planning authorities raise objections, the Secretary of State may ask for modifications of the construction plans or hold a public inquiry to resolve the objections (Department of Energy & Climate Change, 2014). For Nationally Significant Infrastructure Projects, the Planning Inspectorate examines the application and provides opportunities for those with objections to put their views in writing or at hearings. Similar processes operate in Scotland and Northern Ireland. In view of the excessive cost and the environmental and operational disadvantages of the undergrounding of new power lines, the policy of the national grid operator is generally to seek overhead connections wherever possible. Undergrounding is

considered where there are exceptional constraints such as dense urban areas or protected landscapes (National Grid, 2009).

The government position on EMF is summarised in the National Policy Statement for Electricity Networks Infrastructure (EN-5) which, together with the Overarching National Policy Statement for Energy (EN-1), provides the primary basis for decisions taken by the Infrastructure Planning Commission on Nationally Significant Infrastructure Projects (Department of Energy & Climate Change, 2011). The response to SAGE has led to a voluntary code of practice for the electricity industry for the optimal phasing of all new high-voltage power lines (132 kilovolt and higher) and for the optimal phasing of existing power lines when they undergo maintenance to replace the conductors. The costs should be reasonable compared to the benefits, as defined in the 2007 SAGE report, and the code of practice does not prescribe any particular methodology for calculating the strength of the magnetic field (Department of Energy & Climate Change, 2012a).

A second code of practice specifies how the exposure guidelines should be applied. This code of practice adopts the basic restrictions on induced current density in the EU recommendation. However, based on recommendations by the Health Protection Agency, field levels that are higher than the reference levels in the EU recommendation are used to assess compliance of overhead power lines directly with the basic restrictions. These reference levels are 9000 volt per metre for electric fields and 360 microtesla for magnetic fields, assessed at 1 metre above ground and with maximum continuous current load (Department of Energy & Climate Change, 2012b).

A third code of practice aims to minimise the risk of microshocks, annoying electric discharges that can occur when conducting objects such as metal rails or fences are charged in the electric field of a power line. Where this is reasonably practicable, electricity companies will avoid designing new power lines that create electric fields of 5000 volt per metre or greater in homes, other land in residential use (for example hostels and care homes) and schools. They will also make information available to the public and consider helping the landowner to reduce the risk of microshocks via earthing or screening (Department of Energy & Climate Change, 2013).

The codes of practice have also been accepted by all the devolved administrations within the UK (EMFs.info, 2016). Following SAGE's Second Interim Assessment, The Energy Networks Association has published Engineering Recommendation G92, which sets out a number of measures designed to reduce magnetic fields from low voltage distribution equipment, mainly endorsing and formalising existing best practice (ENA, 2013).

6.4 Future plans

The present regime for public exposure to EMF from the power system was effectively set in 2009. Since then, there has been localised opposition to this regime in the context of applications for particular power lines, but there have been no moves to change the national

policy. There are no indications that UK government policy on public exposure to EMF will change in the near future in the absence of changed evidence of harm. Public Health England keeps emerging scientific studies worldwide under review and will update its advice to government as and when necessary.

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7 Discussion

7.1 Policies compared

The five countries selected as case studies in this report have all used the epidemiological association between magnetic fields from power lines and an increased risk of childhood leukaemia as an element in formulating some degree of precautionary policy (for a comparative summary, see Table 1). They differ, however, in the extent of the precautionary measures adopted and in the extent to which arguments other than potential health effects have determined policy.

With regard to limitation of the magnetic flux density, the Belgian region Flanders has a legal indoor limit of 10% of the reference level in the EU recommendation. The other Belgian regions, France, Germany and the Netherlands apply the reference level in the EU recommendation (100 microtesla) either as a legal limit for new installations or as an advisory limit for all installations. The UK applies a higher reference level (360 microtesla) to assess compliance with the same basic restrictions. France, the Netherlands and the Belgian regions of Flanders and Brussels also have an advisory limit of 1 or 0.4 microtesla, depending on a combination of epidemiological and technical or economic considerations. Germany has a more general legal obligation to minimise fields for new installations. The UK has a policy to apply only low-cost field reduction measures.

With regard to the type of installation that produces the magnetic field, the precautionary policies of Flanders, the Netherlands and the UK apply to new sensitive locations near overhead high-voltage power lines. The precautionary policy in France applies to new sensitive locations near overhead high-voltage power lines, underground cables, transformers and bus bars and that of Brussels only to transformers (possibly reflecting the nature of the local electricity infrastructure). In Germany, the obligation to minimise low frequency fields applies to all new fixed electrical facilities (power lines, underground cables, transformer stations, electric rail conductors and similar installations) near sensitive locations. Where precautionary policy is limited to power lines, the arguments tend to focus on the possibly increased risk of childhood leukaemia. Where the precautionary policy is applied to a broad range of electrical facilities, a more general argument is given to keep fields as low as reasonably possible in the light of scientific uncertainty.

With regard to the definition of 'sensitive locations' where precautionary policies for magnetic fields apply, that used in the Brussels region is the broadest (all places where children younger than 15 may stay). In Germany and the Netherlands, the policy applies to both homes and schools and other childcare facilities (in the Netherlands: for children younger than 15). In Flanders and France, the precautionary policy for power lines applies to schools and childcare facilities, but not to homes (although the spanning of homes by new power lines in Flanders should be minimised). No sensitive locations are defined in the UK, but the reference levels are applied to properties where members of the public

spend an appreciable proportion of their time. It is not clear why the definitions in some countries or regions exclude homes from (part of) the scope for precautionary measures, since these would normally be the locations where children spend the largest percentage of their time.

In all the countries that were examined, the costs of the practical measures resulting from the precautionary policy were weighed to some degree against the health effects, under the assumption that there is a causal link between magnetic field exposure and an increased risk of childhood leukaemia. However, these assessments start from the assumption that the link is causal and do not incorporate the degree of uncertainty about causality. A formal cost-benefit approach was followed to the greatest extent in the UK, where economic disease burden, costs of technical measures and loss of property value were explicitly weighed (Kandel et al., 2016). Under such a utilitarian approach, only low-cost measures such as optimal phasing are cost-effective, but these may have low acceptability by local residents (von Winterfeldt et al., 2004).

On the basis of the scientific evidence (uncertainty, rarity of childhood leukaemia, rarity of relevant EMF exposure, small effect size) WHO recommends 'very low-cost measures' to reduce exposure when constructing new facilities and designing new equipment (WHO, 2007). A similar conclusion was reached by others in an attempt to apply the 'Bradford Hill' criteria for causality to the scientific evidence in combination with the European Commission's communication on the precautionary principle (Maslanyj et al., 2010). However, WHO also stresses that public trust, cultural values and consensus seeking are important factors in the risk management process and that these may differ between countries (WHO, 2007). Power line policy in the Netherlands seems to have gone the farthest in allowing non-utilitarian arguments (such as societal concerns and acceptability of EMF risks) to influence political decision making.

The application of precautionary policies to magnetic fields from power lines is a relatively recent phenomenon in most of the countries studied for this report. In future years, it will be useful to analyse how the different policies have been adapted in the light of practical experience with their implementation and the most recent scientific insights into the risks of magnetic field exposure.

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Table 1. Overview of policies for magnetic fields near 50 hertz electricity infrastructure in five EU Member States

| | Belgium | France | Germany | Netherlands | UK |
|--|--|--|--|--|--|
| Legal limit (microtesla); EU recommendation: 100 | 10 (Flanders, indoor); 100 (Brussels, Wallonia, near transformers of specified power) | 100 (places accessible to public near new or modified installations) | 100 (places with more than temporary stay of people near installations for electricity transport, transformation ≥ 1 kV) | No fixed limit | No fixed limit |
| Advisory limit (microtesla) | 0.2 (Flanders, indoor); 0.4 (Flanders, new sensitive locations near power line); 10, but 0.4 where possible (Brussels, near transformers) | 1 (new housing near power line, underground cable, transformer or bus bar) | No federal advisory limit; advisory limit in some regions | 0.4 (new situations with sensitive designated use near overhead power line); 100 (existing situations) | 360 (applied to properties where members of the public spend an appreciable proportion of their time) |
| Policy | Ministerial recommendation: avoid new sensitive locations in magnetic field zone; minimise spanning of sensitive locations and offer buy-out (Flanders) | Ministerial recommendation: minimise creation of new sensitive locations in magnetic field zone | Law: exhaust all possibilities to minimise fields when creating new or substantially modified low frequency facilities near sensitive locations; new power lines ≥ 220 kV may not span places of long-term stay | Ministerial recommendation: avoid as much as reasonably possible creating new situations with long-term exposure of children in magnetic field zone of overhead power line | Government policy statement: government supports low-cost field reduction measures for new power lines, but not magnetic field exclusion zones, re-routing or undergrounding |
| Motivation | Precautionary principle, probability and seriousness of effect (childhood leukaemia) weighed against size of exposed population and societal impact (Flanders) | Balance between epidemiological evidence (childhood leukaemia), technical possibilities and economical viability | General strategy to avoid or minimise unnecessary exposure, scientific uncertainty (primarily on possibly increased risk of childhood leukaemia) | Precautionary principle, scientific data (association with childhood leukaemia) and public concern regarding high-voltage power lines | Measures should be proportional to the evidence base on potential health risks; balance of scientific evidence has not proven a causal link with cancer or any other disease |

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Appendix: Search strategy

A. PubMed

(magnetic OR electric OR electromagnetic OR emf) AND (low frequ* OR elf OR lf) AND field* AND (policy OR policies OR regulation OR recommend* OR advi*)

search 25/07/2016

255 results, 7 relevant

B. Scopus

TITLE-ABS-KEY ((magnetic OR electric OR electromagnetic OR emf) AND ("low frequency" OR elf OR lf) AND field* AND (policy OR policies OR regulation OR recommend* OR advi*))

539 results, 3 relevant in addition to Pubmed

C. Google

Web searches were conducted via Google advanced search (http://www.google.co.uk/advanced_search). Google has implicit 'AND' for subsequent terms. No word end variants were used, since Google recognises stem variants (see:

http://www.googleguide.com/interpreting_queries.html)

The first 100 results per search were checked (for individual countries, no relevant results are usually found by then).

- *International (www.google.co.uk), no country specified*

(magnetic OR electric OR electromagnetic OR emf) (low frequency OR elf OR lf) field (policy OR policies OR legislation OR regulation OR recommendation)

52000000 results, first 100 checked

- *UK (www.google.co.uk)*

(magnetic OR electric OR electromagnetic OR emf) (low frequency OR elf OR lf) field (policy OR policies OR legislation OR regulation OR recommendation)

country: UK

first 100 results checked (no total results given)

(magnetic OR electric OR electromagnetic OR emf) field (power line OR transmission line OR electricity line)

country: UK

first 100 results checked (no total results given)

(policy OR policies OR legislation OR regulation OR recommendation)
(power line OR transmission line OR electricity line)

country: UK

first 100 results checked (no total results given)

- *Belgium (www.google.be)*

(magnetisch OR elektrisch OR elektromagnetisch OR emv) (laagfrequent OR elf OR lf) veld (beleid OR wetgeving OR regelgeving OR aanbeveling)

land: België

first 100 results checked (no total results given)

(magnetisch OR elektrisch OR elektromagnetisch OR emv) veld (hoogspanning* OR transmissie*)

land: België

12 results

(beleid OR wetgeving OR regelgeving OR aanbeveling) (hoogspanning* OR transmissie*)

land: België

18 results

(magnetique OR électrique OR électromagnétique) (basse fréquence OR bf) champ (politique OR législation OR réglementation OR recommandation)

pays: Belgique

first 100 results checked (no total results given)

(magnetique OR électrique OR électromagnétique) (basse fréquence OR bf) champ (haute tension OR transmission)

pays: Belgique

first 100 results checked (no total results given)

(politique OR législation OR réglementation OR recommandation) (haute tension OR transmission)

pays: Belgique

first 100 results checked (no total results given)

- *France (www.google.fr)*

(magnetique OR électrique OR électromagnétique) (basse fréquence OR bf) champ (politique OR législation OR réglementation OR recommandation)

pays: France

first 100 results checked (no total results given)

(magnetique OR électrique OR électromagnétique) (basse fréquence OR bf) champ (haute tension OR transmission)

pays: France

first 100 results checked (no total results given)

(politique OR législation OR réglementation OR recommandation) (haute tension OR transmission)

pays: France

first 100 results checked (no total results given)

- *Germany (www.google.de)*

(magnetisch OR elektrisch OR elektromagnetisch OR emf)
(niederfrequent OR enf OR nf) feld (politik OR gesetzgebung OR
regelung OR anordnung OR vorschrift OR empfehlung)
land: Deutschland

first 100 results checked (no total results given)

(magnetisch OR elektrisch OR elektromagnetisch OR emf)
(niederfrequent OR enf OR nf) feld (hochspannung* OR stromleitung OR
freileitung OR übertragungsleitung)

land: Deutschland

first 100 results checked (no total results given)

(politik OR gesetzgebung OR regelung OR anordnung OR vorschrift OR
empfehlung) (hochspannung* OR stromleitung OR freileitung OR
übertragungsleitung)

land: Deutschland

first 100 results checked (no total results given)

D. Open Grey

(magnetic OR electric OR electromagnetic OR emf) (low frequency OR
elf OR lf) field (policy OR policies OR legislation OR regulation OR
recommendation)

1 result, not relevant

(magnetic OR electric OR electromagnetic OR emf) field (power line OR
transmission line OR electricity line)

79 results, 1 relevant but outdated (1987)

(policy OR policies OR legislation OR regulation OR recommendation)
(power line OR transmission line OR electricity line)

73, none relevant

Dutch search terms

no results

(magnetique OR électrique OR électromagnétique) (basse fréquence OR
bf) champ (politique OR législation OR réglementation OR
recommandation)

no results

(magnetique OR électrique OR électromagnétique) (basse fréquence OR
bf) champ (haute tension OR transmission)

7 results, none relevant
(politique OR législation OR réglementation OR recommandation) (haute
tension OR transmission)

149 results, none relevant

(magnetisch OR elektrisch OR elektromagnetisch OR emf)
(niederfrequent OR enf OR nf) feld (politik OR gesetzgebung OR
regelung OR anordnung OR vorschrift OR empfehlung)

no results

(magnetisch OR elektrisch OR elektromagnetisch OR emf)
(niederfrequent OR enf OR nf) feld (hochspannung* OR stromleitung OR
freileitung OR übertragungsleitung)

no results

(politik OR gesetzgebung OR regelung OR anordnung OR vorschrift OR
empfehlung) (hochspannung* OR stromleitung OR freileitung OR
übertragungsleitung)

2 results, none relevant

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Erratum:

In Table 1 on page 50, the text in the second column (France), second row should read:

"1 (new hospitals, maternity wards and childcare facilities near power line, underground cable, transformer or bus bar)"

Voor akkoord, 23 oktober 2017

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