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Public Exposure to Non-ionising Radiation from Major Electricity Infrastructure in Ireland

Authors: Anna Mölter, Hamed Jalilian, Martin Röösli, Frank de Vocht and Francesco Pilla.

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Rialtas na hÉireann
Government of Ireland

Environmental Protection Agency

The EPA is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

The work of the EPA can be divided into three main areas:

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Knowledge: Providing high quality, targeted and timely environmental data, information and assessment to inform decision making.

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> Provide independent evidence-based reporting, advice and guidance to Government, industry and the public on environmental and radiological protection topics;
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The EPA is managed by a full time Board, consisting of a Director General and five Directors. The work is carried out across five Offices:

1. Office of Environmental Sustainability
2. Office of Environmental Enforcement
3. Office of Evidence and Assessment
4. Office of Radiation Protection and Environmental Monitoring
5. Office of Communications and Corporate Services

The EPA is assisted by advisory committees who meet regularly to discuss issues of concern and provide advice to the Board.

epa Research

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Identifying pressures

Major electricity infrastructure, such as high-voltage power lines, transformer stations and substations, emits non-ionising radiation in the form of extremely low-frequency electromagnetic fields (ELF EMFs). Potential health effects associated with long-term exposure to ELF EMFs have been a concern since the late 1970s, and the International Agency for Research on Cancer has classified ELF EMFs as a category 2B risk, which means they are "possibly carcinogenic to humans". However, epidemiological studies of health risks of ELF EMF exposure have reported varying results, and a causal relationship has not been established.

The objectives of this project were to review the published literature on:

- studies on population exposure to ELF EMFs from major electricity infrastructure;
- epidemiological studies on health risks associated with ELF EMF exposure;
- current EU policies on ELF EMF exposure, monitoring strategies and methods to reduce exposure;
- risk communication strategies for ELF EMF exposure risks.

Informing policy

Major electricity infrastructure developments are periodically required to ensure the security of the energy supply. However, these types of developments often attract public opposition, and during previous developments in Ireland, health risks due to exposure to EMFs were one of the concerns. A major electricity infrastructure project that is currently ongoing in Ireland is the Celtic Interconnector, an undersea electricity link between Ireland and France with a transmission capacity of 700 MW via 320 kV power lines.

Under the Radiological Protection Act 1991 (Non-Ionising Radiation) Order 2019 (SI No. 190 of 2019), the EPA was assigned responsibilities for public exposure to non-ionising radiation, which includes emissions from existing and new electricity infrastructure, such as the Celtic Interconnector. Therefore, it is important for the EPA to have an up-to-date knowledge base of exposure levels associated with ELF EMFs from major electricity infrastructure, and of potential health risks. Furthermore, the EPA needs to be informed about state-of-the-art policies in EU countries and risk communication strategies, to respond to public concerns.

Developing solutions

This report provides a number of recommendations for Ireland, including recommendations on the reference level for public exposure to ELF EMFs from major electricity infrastructure, as well as on regulatory monitoring practices, risk communication, and further research and capacity building. With regard to public exposure to ELF EMFs from major electricity infrastructure, it is recommended that Ireland implements the reference level recommended by the EU. In addition, the introduction of precautionary policies is recommended for the construction of new high-voltage electricity infrastructure in Ireland and the construction of new buildings. With regard to regulatory monitoring, it is recommended that surveys are carried out after the construction of new high-voltage infrastructure, or after modifications of existing infrastructure that will change the voltage or current. The results of these surveys should be made publicly available. To improve risk communication, the introduction of a process through which local authorities can request an ELF EMF field survey is recommended if there is significant public concern. Finally, this report shows that there are great opportunities for further research and capacity building on this topic in Ireland.

EPA RESEARCH PROGRAMME 2021–2030

Public Exposure to Non-ionising Radiation from Major Electricity Infrastructure in Ireland

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EPA Research Report

Prepared for the Environmental Protection Agency

by

University College Dublin

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The EPA Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Executive Summary

The aim of the project "Public exposure to non-ionising radiation from major electricity infrastructure in Ireland" was to review the published literature on extremely low-frequency (ELF) electromagnetic fields (EMFs), which are a form of non-ionising radiation, from major electricity infrastructure. This topic is highly relevant in Ireland, owing to the current expansion of the high-voltage network, including the construction of various interconnectors such as the Celtic Interconnector, which is a major electricity infrastructure project connecting the electricity grids of Ireland and France. Specific objectives of this project were to review international, and in particular European, publications on (1) ELF EMF exposure from electricity infrastructure, (2) potential health effects associated with this exposure, (3) current policies and monitoring strategies in Europe and (4) risk communication strategies for ELF EMF exposure. The outputs from this project were individual reports for each of the objectives listed above, and also repositories of the publications identified for objectives 1 and 2. The final project report presented in this document summarises the main findings from each report and provides recommendations for managing public exposure to ELF EMFs in Ireland.

Chapter 1 serves as an introduction to the work and details the objectives of the study. Chapter 2 introduces the concept of ELF EMF exposure assessment and describes sources of ELF EMF exposure within major electricity infrastructure. It provides a brief overview of the electricity infrastructure in Ireland, including the existing and planned electricity interconnectors. It also summarises the findings from a systematic review of the peer-reviewed literature on public exposure to ELF EMFs from electricity infrastructure. The mean and maximum magnetic and electric field levels measured near power lines and built-in transformers identified in the literature are also presented.

Chapter 3 examines the association between public exposure to ELF EMFs from electricity infrastructure and human health problems. To avoid duplicating work presented in previous reports commissioned by the Irish government, a two-stage approach was used. The first stage was an umbrella review of epidemiological studies. An umbrella review is a review type that aggregates and analyses findings from previous systematic reviews, rather than from individual studies. The umbrella review analysed the association between ELF EMF exposure and health outcomes belonging to three groups: cancer, neurodegenerative diseases, and developmental and birth outcomes. The second stage was a systematic review of the peer-reviewed literature published since 2015, which was the year a previous government report on the topic was published. The purpose of the systematic review was to evaluate recent knowledge and developments in this field of study. The health outcomes analysed in the systematic review were birth outcomes and infertility, since systematic reviews on cancer and neurodegenerative diseases have been published in the last 2 years.

Chapter 4 focuses on policies on public ELF EMF exposure in European countries. It begins by describing the international and EU recommendations to limit public exposure and summarises if and how these have been implemented in various European countries. This chapter also explains additional precautionary policies that may be adopted and presents examples. Furthermore, it depicts monitoring strategies for ELF EMFs in European countries, and briefly describes methods that can be used to reduce public exposure.

Chapter 5 addresses risk communication on ELF EMFs from electricity infrastructure. It starts with a general overview of concepts and elements of risk communication in environmental health. It then summarises studies that have investigated aspects of risk communication during electricity infrastructure developments. Chapter 5 finishes with a brief description of an ongoing research programme in Germany that specifically focuses on risk communication and risk perception of the expansion of the German high-voltage power grid.

This report concludes with recommendations for practices and future research in Ireland (Chapter 6). The recommendations are based on the literature reviewed during this project, and they have been

grouped into four subtopics: reference level and precautionary policies, regulatory monitoring, risk communication, and research and capacity building. The recommendations provided aim to support the EPA in its duty to advise the public and the government on public exposure to ELF EMFs from electricity infrastructure and to monitor public exposure to ELF EMFs in Ireland.

1 Introduction

1.1 Background and Justification

The flow of electricity through electrical wires and devices produces non-ionising radiation in the form of electromagnetic fields (EMFs). Within the electromagnetic spectrum, non-ionising radiation can be divided into four categories based on its frequency, which is measured in hertz (Hz): static electric fields (EFs) and magnetic fields (MFs) (0 Hz), extremely low-frequency (ELF) fields (> 0 Hz to ~ 300 Hz), intermediate-frequency fields (300 Hz to ~ 100 kHz) and radiofrequency (RF) fields (100 kHz to 300 GHz) (Röösli, 2014). The RF field frequency range also includes microwaves (300 MHz to 300 GHz). Major electricity infrastructure refers to power plants, overhead and underground power lines and cables, and electricity substations and transformers. In Europe, alternating current (AC) power lines and cables operate at a frequency of 50 Hz, and therefore produce ELF EMFs at this frequency, also referred to as power-frequency EMFs. Direct current (DC) power lines and cables produce static fields; however, DC power lines are not common, as the majority of power lines operate on AC. In fact, there are no DC overhead power lines in Ireland (EirGrid, 2022).

Potential health effects associated with long-term exposure to ELF EMFs have been a concern since the late 1970s. Since then, a number of epidemiological studies have investigated childhood cancer and ELF EMF exposure. Pooled analyses of these studies showed an elevated risk of childhood leukaemia associated with high ELF EMF strengths within the child's home (Ahlbom *et al*., 2000). In 2002, the International Agency for Research on Cancer (IARC) classified ELF EMFs as a category group 2B ("possibly carcinogenic to humans") risk agent. In 2015, the EU's Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) confirmed that epidemiological studies have consistently found an increased risk of childhood leukaemia associated with daily average ELF EMF exposures of > 0.3–0.4 µT (SCENIHR, 2015).

In 1998, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published "Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz)" (ICNIRP, 1998). These guidelines recommended a reference exposure limit for 50 Hz MFs of 100 µT for the general public. In 1999, the EU published a "Recommendation on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)" (EU, 1999), which was based on the numerical values provided by the ICNIRP. However, since then no other European legislation on ELF EMF exposure limits has been approved. Because EU recommendations are not legally binding for Member States, it is open to EU countries how to implement the EU 1999 Recommendation on public exposure to EMFs. In 2010, the ICNIRP updated its guidelines for the frequency range 1 Hz to 100 kHz (ICNIRP, 2010). For 50 Hz MFs, a reference exposure limit of 200 µT was proposed for the public (ICNIRP, 2010). In contrast, the EU did not update its recommendations on the recommended exposure limits and instead reconfirmed the 1999 Recommendation in 2009 (European Parliament, 2009). In Ireland, the EU 1999 Recommendation has not been transposed into Irish law to date, but the recommended reference levels are commonly applied following best practice.

The Celtic Interconnector is a major electricity infrastructure project that is currently under construction in Ireland. The Celtic Interconnector is an undersea link connecting the electricity grids of Ireland and France with the aim of strengthening the security of the electricity supply, supporting the development of sustainable electricity production and enabling European consumers to benefit from a larger and more open electricity market. The Celtic Interconnector is due to be completed by 2026. It will have a transmission capacity of 700 MW via a 320 kV DC underground and undersea power cable. The power line will connect, via a transformer station, into Knockraha substation in County Cork. Major electricity infrastructure projects often attract public opposition, and residents of Knockraha village have protested against the planned development (O'Riordan, 2021). Similar protests occurred during EirGrid's Grid25 implementation programme in 2014, which included the construction of 800 km of new power lines and upgrades to 2000 km of existing power lines in Ireland (Ryan, 2014). Other major electricity infrastructure, such as the North–South Interconnector, has been affected by similar public opposition (O'Brien, 2018). This highlights the importance of providing accurate information about potential risks associated with ELF EMFs from major electricity infrastructure.

The EPA was assigned responsibilities for public exposure to non-ionising radiation between 0 Hz and 300 GHz in 2019 under the Radiological Protection Act 1991 (Non-Ionising Radiation) Order 2019 (SI No. 190 of 2019). In view of the current construction of the Celtic Interconnector and other major electricity infrastructure, it is important for the EPA to have an up-to-date knowledge base of exposure and health concerns associated with ELF EMFs from major electricity infrastructure, and also state-of-the-art policies and communication strategies, to respond to public concerns.

1.2 Objectives

The overall objective of this project was to review published literature on public exposure to ELF EMFs from major electricity infrastructure. This project reviewed international and in particular European publications on ELF EMF exposure, health effects, policies and science communications to summarise the current state of knowledge and to provide recommendations in the Irish context. Specific objectives were to carry out:

- a systematic review of studies on exposure of the population to ELF EMFs from major electricity infrastructure;
- an umbrella review of epidemiological studies on health risks associated with exposure to ELF EMFs from major electricity infrastructure;
- a state-of-the-art review of current EU policies on ELF EMFs, monitoring strategies and methods to reduce public exposure;
- a state-of-the art review of science communication strategies for ELF EMF exposure risks.

Each of the above objectives has been addressed in an individual report submitted to the EPA, which is available on the project website. The following chapters summarise key findings from each of these four reports. The final chapter presents overall conclusions and provides recommendations.

2 Exposure to ELF EMF from Electricity Infrastructure

2.1 Introduction to ELF EMF Exposure Assessment

EMFs do occur naturally, but they are also produced by sources such as electrical infrastructure and devices (Staebler, 2017). EMFs are ubiquitous in the environment, and they can be separated into EFs, MFs and EMFs. In the low-frequency range of the electromagnetic spectrum, which usually encompasses frequencies up to 100 kHz, MFs (also known as B-fields, measured in teslas (T)) and EFs (also known as E-fields, measured in volts per metre (V/m)) are not proportional to each other and need to be measured separately.

Exposure is defined as an object, in this case a person, coming into contact with an agent, in this case EMFs, over a specific period of time (Ott *et al.*, 2006). To assess human exposure to EMFs a number of methods can be used, which can be broadly divided into direct and indirect methods (Gallastegi *et al.*, 2016). Direct methods use calibrated monitoring instruments to measure the electric and/or magnetic fields. Different instruments are used depending on the type of measurements that are carried out. Spot measurements assess fields at a specific location and a specific point in time. Spot measurements are often used to map the spatial distribution of ELF EMFs around electricity infrastructure (Paniagua *et al.*, 2004; Bagheri Hosseinabadi *et al.*, 2020). Fixed-location monitoring measures fields continuously at a specific location over a longer period of time (Schüz *et al.*, 2000; Gallastegi *et al.*, 2016). The duration of fixed-location monitoring can range from several hours to several days, depending on the aim of the measurements. Fixed-location monitoring can be used in epidemiological studies, e.g. to monitor ELF EMFs inside a subject's home (Salvan *et al.*, 2015), and can also be used for routine monitoring. Personal measurements use lightweight monitors attached to a person to measure exposure in all locations that the person visits over a specific period of time. Personal measurements can provide an estimate of the total exposure (in a specific frequency range) of a subject from all environmental sources (Gajšek *et al.*, 2016). However, personal ELF measurements typically do not differentiate between exposures from different sources, and personal monitoring devices can be obtrusive. It should also be noted that personal measurements are used to monitor only the MF, as the human body influences the EF (Brune *et al.*, 2003).

Indirect methods estimate exposure based on physical or spatial parameters, models or established algorithms. Exposure estimates from indirect methods have usually been validated through direct methods in the past. A common indirect method is to estimate exposure based on a very simple model using solely the distance to an ELF EMF source. Both ELF EFs and ELF MFs decrease with increasing distance to the field source; therefore, distance in metres can be used as a proxy measure of exposure to major sources such as overhead power lines, but this is limited to small and complex sources such as electrical infrastructure or transformer stations. Another indirect method is wire code. In this method, power lines that are in close proximity to houses are inspected visually. Parameters such as the size and arrangement of the wires, distance to the origin of electric current and distance between power lines and houses are used to estimate the ELF MF. Although some relationships between the measured ELF MF and the wire coding classification have been observed in studies, wire codes tend to misclassify homes, although they are sensitive enough to identify high-exposure situations (Kheifets *et al.*, 1997). Finally, specialised software packages can be used to calculate ELF EMFs near power lines using more sophisticated input data such as the geometry of the conductors, the voltages and currents (amplitude and phase angle) in the conductors and the return paths (Dürrenberger *et al.*, 2014). However, calculating ELF EMFs near powerlines over long periods is difficult, as the necessary input data are rarely available and the geometry of the conductors is temperature dependent. However, large-scale simulations of time-averaged ELF MFs are feasible using simplified input data such as a specific height above the ground (Bürgi *et al.*, 2017).

2.2 Sources of ELF EMF from Electricity Infrastructure

There are many sources of ELF EMFs in a person's everyday environment, such as household appliances, electric wiring and sockets, and electric railways. However, this report focuses on ELF EMFs emitted by major electricity infrastructure. Major electricity infrastructure consists of an interconnected system of power plants, transmission lines, substations and distribution lines, ending with the electrical wiring in houses (Blume, 2016).

Power plants produce electrical energy on a real-time need basis, i.e. they do not usually store energy. Within power plants, high ELF MFs can be found around the generator and the initial transmission infrastructure (especially bus bars) (Röösli, 2014). Power plants are not accessible to the public; therefore, the potential for the general public to be exposed to these high ELF MFs is low. However, operators and technicians working in power plants can be exposed to high ELF MFs (Bagheri Hosseinabadi *et al.*, 2020).

Transmission lines are power lines that connect power plants to substations and distribution stations. Transmission lines can transfer AC or DC electricity, and they can be located overhead or underground. Transmission lines vary in length and operating voltage. It has been calculated that overhead transmission lines (three wires horizontally arranged) operating at 600 A and 220 kV can typically emit ELF MFs around 3.5 μT and 1.9 μT at 10 m and 20 m distances, respectively (King, 1998). Outside a corridor of 50 m, the calculated magnetic flux density is less than 1 μT, and at a distance of 100 m it decreases to 0.036 μT. The calculated EF strength at 100 m is 11 V/m (King, 1998). Owing to the fluctuation in power required by users (e.g. industries, households), the electrical current, or load, in transmission lines varies constantly. This means that the MFs around transmission lines also vary constantly, and the average emission levels can be four to five times lower than the maximum emission levels depending on the load. Underground transmission lines are cables that are buried in the ground, either with or without a conduit. Underground transmission lines are typically located 1–3 m below the surface, and therefore exposure levels directly above a cable can be higher than exposure levels underneath overhead lines. However, underground cables are placed closer together; therefore, ELF MFs decrease more rapidly in a horizontally perpendicular direction than those of overhead lines. Moreover, ELF EFs from underground cables are mostly shielded by the ground, so the public are not likely to be exposed to these fields.

Substations usually receive power from a high-voltage transmission line, and then pass it through stepdown transformers into a lower-voltage sub-transmission line or distribution line. Similar to power plants, access to substations is restricted; therefore, the potential for the general public to be exposed is low.

Distribution lines transmit the power from substations to buildings and tend to operate on a lower voltage than transmission lines. Additional small transformers may be mounted on poles along distribution lines to further step down the voltage to the level used by appliances. Some industrial, commercial and apartment buildings may also contain transformers. In some countries, distribution lines may be sited underground in densely populated urban areas (Bowman, 2014).

2.3 Electricity Infrastructure in Ireland

2.3.1 *Transmission and distribution*

The electricity infrastructure in Ireland is divided into the transmission network and distribution network (Government of Ireland, 2021). EirGrid, a state-owned company, operates the transmission system, which means that it manages the power flows and ensures that the transmission network can meet the electricity demand (ESB, 2022). ESB Networks (majority owned by the Irish government) owns, builds and maintains the transmission network, and it operates and builds the distribution network (ESB, 2022). The energy transmission and distribution networks are regulated by the Commission for Regulation of Utilities (CRU) (CRU, 2022). CRU issues licences to EirGrid and ESB Networks to distribute electricity throughout the network. Its main regulatory role is to protect electricity customers' financial interests and to maintain security of supply (CRU, 2022).

The transmission system owned by ESB consists of substations, overhead lines, underground cables, submarine cables and transformers operating on voltages from 110 kV to 400 kV. An open access interactive map of the Irish electricity infrastructure can be found here: https://openinframap.org/#6/53.34/-7.731. The distribution network connects the transmission network to customers in Ireland (ESB, 2022). In the Dublin area the distribution network operates at 110 kV, while in the rest of the country it operates at low voltages (e.g. 38 kV, 20 kV, 10 kV). Owing to the proportion of the Irish population living in rural areas, the distribution network length per capita in Ireland is four times larger than the European average. There are six times more overhead lines than underground cables (ESB, 2022).

2.3.2 Electricity interconnectors in Ireland

Electricity interconnectors are high-voltage lines and cables that link the electrical infrastructures of neighbouring countries. Because Ireland is an island, electricity interconnection uses undersea cables. There are two existing interconnectors in Ireland. The Moyle Interconnector is an undersea high-voltage direct current (HVDC) link between Northern Ireland and Scotland. It was commissioned in December 2001 and has a total capacity of 500 MW. It consists of an HVDC converter station in Ballycronan More, County Antrim, which is connected to two 250 kV underground (8.5 km) and submarine (55 km) DC cables, each with a transmission capacity of 250 MW. The East–West Interconnector is an undersea HVDC link between Ireland and Wales. It was commissioned in 2012 and also has a capacity of 500 MW. Unlike the Moyle Interconnector, it uses a 200 kV HVDC light transmission system. The East–West Interconnector consists of 186 km of submarine DC cables, a substation near Rush North Beach, 75 km of underground DC cables and a converter station in County Meath.

In addition, there are two interconnectors that are currently under development. The Greenlink is an undersea HVDC link between Ireland and Wales, funded by a private investment firm. Construction of the Greenlink started in 2022, and it is expected to be commissioned by 2024. The Greenlink will have a capacity of 500 MW and will connect to the Irish grid via EirGrid's Great Island substation, County Wexford. It will consist of a converter station near the Great Island substation and two 320 kV underground (40 km) and submarine (160 km) DC cables. The Celtic Interconnector is an undersea HVDC link between Ireland and France. Construction work of cable trenches for the Celtic Interconnector commenced in spring 2023; it is expected to be commissioned by 2026. The Celtic Interconnector will have a transmission capacity of 700 MW and will connect to the Irish grid via Knockraha substation, County Cork. The converter station will be built at Ballyadam, with a 320 kV underground (40 km) DC cable to the sea. The submarine DC cable will be 500 km long.

No peer-reviewed study has been published that has measured the total public exposure from electricity interconnectors. However, some data are available for the components of a submarine electricity interconnector. The interconnectors connect into the transmission system via 400 kV substations. Results from a monitoring study near the 400 kV Dunstown substation in County Kildare show that that the average MF at 0 m distance is 0.1 μT, and the average electric field at 5 m distance is 0.05 kV/m (RPS Group, 2014). Limited data are available for underground and submarine DC cables. In a presentation prepared by Exponent consultants in September 2021 on behalf of EirGrid, it is stated that the static MF 1 m above the East–West Interconnector's DC transmission line is 13 μT, and that the static MF above the DC transmission line of the Celtic Interconnector will be 15 μT (Exponent, 2021). No reference or source is provided for these values, and it is unclear whether the value for the East–West Interconnector is derived from measurements or modelling, and which geographical location and time period it refers to. In contrast, a study in Germany measured MFs ranging from 21.81 μT to 47.81 μT 1 m above ground of a 380 kV DC cable with an embedding depth of 1.5 m (Energie-Forschungszentrum Niedersachsen, 2012). For a 380 kV submarine cable a magnetic flux density of 161.4 μT has been measured 1 m above the seabed (Merck and von Nordheim, 2000). It should be noted that the recommended reference level for static MFs is 400 mT (ICNIRP, 2009), which is considerably higher than the measured values and higher than the reference level for fields at 50 Hz (i.e., 100 μT) (EU, 1999).

2.4 Previous Measurements in Ireland

In 2014, EirGrid commissioned RPS consultants to write a report on "Human health impacts of EMF" (RPS Group, 2014). This report consisted of two parts, a literature review and a measurement survey of ELF EFs and MFs at seven sites, which represented high-voltage overhead lines, underground cables and substations (all were AC infrastructure). The maximum ELF EF and MF levels measured at these sites are shown in Table 2.1. The measurement survey found that the MF strength measured at all sites was below the ICNIRP public exposure reference level (see section 4.1).

2.5 Systematic Review of ELF EMF Exposure Studies in Europe

2.5.1 Method

The protocol for the systematic review of public ELF EMF exposure has been published via OSF (https://osf.io/b4cwx). In brief, four databases (Web of Science, PubMed, Embase and Xplore of IEEE) and the EMF-PORTAL (https://www.emf-portal.org/en) were systematically searched from January 2007 to March 2022 for population exposure studies of ELF EMFs based in European countries. Keywords related to “exposure” (“magnetic field”, “electric field”, “extremely low frequency”, “ELF”, “electromagnetic field”, “power line”, “electrical substation”, “power substation”, “electric utility”, “power plant”, “electrical grid”, “transmission line”, “distribution line”, “hybrid line”, “HVDC”, “HVAC”, “hybrid coil” and “transformer”) and “population” (“general population”, “public”, “children”, “student”, “school”, “adolescent”, “adult”, “personal exposure”, “personal measurement” and “exposimetry”) were used. The title, abstract and keywords of identified documents were screened for eligibility; a list of eligibility criteria is provided in the protocol. From eligible studies the year of publication, country, sources of ELF EMF, ELF EMF assessment method, ELF EMF measurement instrument/model, population, covariates, study design and variability of exposure were extracted.

2.5.2 Results

During the database searches, 6231 unique peer-reviewed articles were identified. After screening the titles and abstracts, 168 papers remained. After examination of the full texts, 26 studies were included in the review. A detailed flow diagram of the selection process is shown in the deliverable D2.1 report.

The selected studies were carried out in 15 European countries. All studies reported ELF MF levels, but only four publications reported ELF EF levels. Where specified, the main sources of exposure were power lines, built-in transformers and substations. However, some studies measured ELF EMF exposure levels without considering the exposure sources. Half of the included studies used more than one exposure assessment method. Spot measurements ($n = 16$) were the main method used, followed by fixed-location monitoring ($n = 13$), personal measurements (n=9)

Table 2.1. Maximum ELF MF and EF levels measured near electricity infrastructure in Ireland by distance from source

		MF (μT)			EF (V/m)		
		Distance (m)					
Infrastructure source	Voltage (kV)	0	50	100	0	50	100
Overhead power line	400	3.74	0.70	0.21	4.72	0.98	0.24
	220	4.97	0.51	0.15	4.55	0.41	0.12
	110	2.44	0.22	0.06	3.16	0.19	0.06
Underground power line	220	26.01	0.34 (at 35 m)				
	110	2.32	0.11 (at 12 m)				
Substation	400	0.13	0.10 (at 10 m)		0.07	0.12 (at 15 m)	
	220	0.12	0.36 (at 30 m)		0.04	0.02	
	110	0.07	0.06		0.03	0.01	

Data source: RPS Group (2014).

Table 2.2. Summary of measured ELF MF levels (µT) by source[a] and measurement method

Type		Arithmetic mean (*n*)[b]	Maximum (*n*)[c]
Source	Power line	0.55 (101)	7.3 (25)
	Built-in transformer	0.48 (72)	139 (66)
Measurement method	Spot	2.86 (120)	37 (58)
	Fixed location	0.33 (33)	15.6 (14)
	Personal	0.13 (72)	139 (47)

[a]The distance to the source was not clearly described in all studies.

[b]The arithmetic mean value of reported arithmetic means in included studies.

[c]The maximum of the reported maximum values in included studies.

and modelling (*n* = 3). A list of the included studies has been provided in an open repository of literature on ELF EMF monitoring and modelling.[1]

An overview of the mean and maximum measured ELF MF levels in the reviewed studies by source (power line, built-in transformer) and measurement method is shown in Table 2.2. It can be seen that the maximum measured ELF MF levels near overhead power lines did not exceed the reference level of 100 µT recommended by the EU or the reference level of 200 µT recommended by the ICNIRP in 2010. It should be noted that the distance from the meter to the power line was not reported clearly in all studies. When reported, values ranged from 0 m distance from a distribution line to 200 m distance from a transmission line. The maximum measured ELF MF near built-in transformers exceeded the EU 1999 reference level by 39% but was below the ICNIRP 2010 reference level. It should be noted that only a single measurement exceeded 100 µT, with all other measurements being below 100 µT. In studies measuring exposure from built-in transformers, the relative location (e.g. apartment on floor above the source) rather than the distance to the source was reported.

Analysing the reviewed studies by source and measurement method showed that spot measurements of ELF MFs close to power lines, which included overhead cables (0–80 m distance), underground cables (0–11 m distance) and heating cables under pavements (0–125 m distance), had a mean value of 0.84 µT (*n* = 56, range (minimum–maximum) 0.045–5.50 µT). Four studies carried out fixed-location monitoring of ELF MFs in bedrooms of houses close to overhead transmission and distribution lines: the overall mean ELF MF level was 0.084 µT (*n* = 12, range 0.02–0.41 µT). The mean value of personal exposure measurements (*n* = 31) to ELF MFs in subjects who lived near power lines was 0.13 µT (range 0.018–1.33 µT). Typically, in the personal exposure studies, the actual time spent near power lines was not specified; therefore, the proportion of the exposure attributable to power lines is unclear.

In apartment buildings with built-in transformers the mean ELF MF measured using spot measurements in apartments (any room or apartment) was 0.31 µT (*n* = 36, range 0.02–3.03 µT). In studies using fixed-location monitoring in apartment buildings with built-in transformers, the overall mean ELF MF level was 0.49 µT (*n* = 14, range 0.024–3.03 µT). Twenty-two studies carried out personal measurements of residents living in apartment buildings with built-in transformers. The overall mean measured ELF MF in these studies was 0.19 µT (range 0.02–1.03 µT).

Only four studies identified in the systematic review measured ELF EF exposure: one study measured ELF EFs at the power frequency (50 Hz), while the other three studies covered a wider range of frequencies, from 5 Hz to 400 kHz. The overall mean ELF EF was 135.60 V/m (*n* = 19, range 0.82–637 V/m). Three of these studies aimed to assess background ELF EF exposure levels in cities or for populations, rather than measuring close to emission sources. One study measured ELF EFs around overhead power lines; it found a mean ELF EF of 202 V/m (*n* = 7, range 0.82–637 V/m, frequency range 5–32 kHz) (Ztoupis *et al*., 2013).

1 https://lookerstudio.google.com/reporting/4138c48a-9a30-4817-95c0-451a32442bda/page/pDB1C?s=k62ptVLNTtk (accessed 9 November 2023).

3 Health Effects Potentially Associated with Exposure to ELF EMF from Electricity Infrastructure

3.1 Introduction

For several decades, there have been health concerns regarding the exposure of humans to ELF MFs. As described in Chapter 2, ELF MFs are a form of non-ionising radiation emitted from electrical cables and devices, including electricity infrastructure (Jalilian *et al*., 2015). Within electricity infrastructure, the sources with the largest spatial coverage are high-voltage transmission lines operated between 110 kV and 400 kV (SCENIHR, 2009; Gajšek *et al*., 2016). However, among people living near power lines, large variability exists between peak ELF MF exposures (~40 μT or more; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans *et al*., 2002) and typical ELF MF exposures (0.5–3 μT) (SCENIHR, 2009). Several epidemiological studies have reported a significant association between public exposure to ELF MFs and an increased risk of adverse health outcomes, such as an increased risk of childhood leukaemia (Feychting and Ahlbom, 1993; Linet *et al*., 1997; Green *et al*., 1999), neurodegenerative diseases (Huss *et al*., 2009), increased cancer risk (Zhang *et al*., 2016) and reduced birth weight (de Vocht and Lee, 2014; Ren *et al*., 2019).

3.2 Objective

The objective of this part of the project was to summarise research findings on the health effects of public exposure to ELF (50 Hz/60 Hz) EMFs emitted from electric power infrastructures. Four previous reports on ELF EMFs have been published in Ireland (Repacholi *et al*., 2007, RPS Group, 2014, Exponent, 2015, Hall, 2015), which provided systematic reviews of health effects associated with public exposure to ELF EMFs. To avoid duplicating the work of these previous reports, this project used a two-stage approach. The first stage was an umbrella review of epidemiological studies. An umbrella review is a review type that aggregates findings from multiple previous systematic reviews. This review type was selected for two reasons: (1) the health effects of ELF EMFs is a large field with many publications, and it was not feasible within the time frame of the project to review all publications, and (2) a considerable number of systematic reviews have already been published in this field, as well as the Irish reports mentioned above. Therefore, it was deemed to be more efficient to carry out an umbrella review. The health outcomes that were analysed in the umbrella review belonged to three broad groups: cancer, neurodegenerative diseases, and developmental and birth outcomes.

The second stage was a systematic review of the literature published since 2015, which was the publication year of the most recent Irish report (Exponent, 2015). Given the time constraints of this project, we decided that it was possible to review original papers published between 2015 and 2022 on one of the groups of health outcomes listed above, to get an understanding of the most recent original research findings. The group of health outcomes selected for the systematic review was the association between birth outcomes and exposure to ELF EMFs from electricity infrastructure. The reason for selecting this group was that two systematic reviews of childhood leukaemia associated with ELF EMFs were published in 2022 (Amoon *et al*., 2022; Brabant *et al*., 2022), and systematic reviews of dementia (Zhao *et al*., 2021) and amyotrophic lateral sclerosis (ALS) (Filippini *et al*., 2021) were published in 2021. In contrast, the last review of the association between ELF EMFs and birth outcomes was published in 2016 (Lewis *et al*., 2016); thus, this area of research seemed to offer a good opportunity to provide further insights.

3.3 Umbrella Review of Cancer, Neurodegenerative Diseases and Birth Outcomes Potentially Associated with Public ELF EMF Exposure

3.3.1 Methods

The protocol for the umbrella review has been published via OSF (https://osf.io/bjpa4). In brief, three databases (Web of Science, PubMed and Embase) and the EMF-PORTAL (https://www.emf-portal.org/en) were systematically searched from 2007 to 2022. Keywords related to “exposure” (“magnetic field”, “electric field”, “extremely low frequency”, “ELF”, “electromagnetic field”, “electrical substation”, “power substation”, “railway”, “electric utility”, “power plant”, “electrical grid”, “power line”, “transmission line”, “distribution line”, “hybrid line”, “HVDC”, “HVAC” and “transformer”) and “health outcomes” were used. For the health outcomes, we focused on three areas: cancer, neurodegenerative disease, and developmental and birth outcomes. The keywords were “cancer”, “carcinogen*”, “health”, “disease”, “malignant”, “tumor”, “leukaemia”, “lymphoma”, “glioma”, “ALS”, “Alzheimer”, “Parkinson”, “motor neuron disease”, “neurodegenerative”, “dementia”, “reproductive”, “pregnancy”, “birth weight”, “gestational age”, “sperm motility”, “pre-term”, “developmental disorders”, “*fertility”, “birth defects”, “birth outcome”, “fetal growth”, “foetal growth”, “miscarriage”, “abortion”, “stillbirth”, “congenital disorder”, “gestational age” and “birthweight”. The title and abstract of identified reviews were screened for eligibility; a list of eligibility criteria is provided in the protocol. From eligible reviews the following data items were extracted: first author, publication year, exposure unit/source, health outcome, study design, date range, quality instrument, population, number of studies included, type of effect size, summary meta-analytic estimates and corresponding 95% confidence intervals (CIs), random-effect *p*-value and heterogeneity measure. The methodological quality of each included review was assessed with the Assessment of Multiple Systematic Reviews (AMSTAR 2) Tool (Shea *et al*., 2017). This is a 16-item tool for quality assessment and risk of bias.

3.3.2 Results

During the database searches, 3054 unique papers were identified. After screening the titles and abstracts 146 papers remained. After examination of the full texts, 38 reviews were included in the umbrella review. A detailed flow diagram of the selection process is shown in the deliverable D3.1 report.

A list of the systematic reviews included in the umbrella review has been provided in D3.2, “Repository of epidemiological literature identified in the umbrella review and systematic review”. Most of the reviews identified analysed the association between ELF MF public exposure and cancer ($n = 18$), with childhood leukaemia ($n = 10$) being the most common topic (Schüz *et al*., 2007; Pelissari *et al*., 2009; Calvente *et al*., 2010; Kheifets *et al*., 2010; Leitgeb, 2014; Zhao *et al*., 2014; Amoon *et al*., 2018, 2022; Swanson *et al*., 2019; Brabant *et al*., 2022). Four systematic reviews analysed ELF MF public exposure and neurodegenerative diseases (Killin *et al*., 2016; Röösli and Jalilian, 2018; Filippini *et al*., 2021; Zhao *et al*., 2021) and one systematic review analysed developmental and birth outcomes (Lewis *et al*., 2016). Only one review analysed the association between ELF EF public exposure and cancer (Lewis *et al*., 2016). In addition to the reviews identified through the databases research, the systematic review by Ahlbom *et al*. (2000) was included in the umbrella review, as it influenced IARC’s decision to classify ELF MF as a category 2B risk for cancer.

The umbrella review found that risk estimates for childhood leukaemia associated with ELF MF exposure presented in systematic reviews varied largely (see Table 2 in the D3.1 report). Possible reasons for discrepancies in the findings are differences in the exposure assessment methods used, potentially leading to exposure misclassification (Schüz and Ahlbom, 2008). In general, long-term measurements (derived from fixed-location monitoring), calculated ELF MF exposure or a combination of both are considered to be the most robust methods. A subgroup analysis of systematic reviews using long-term measured exposure suggested a dose–response pattern for leukaemia risk (Ahlbom *et al*., 2000; Schüz and Ahlbom, 2008; Kheifets *et al*., 2010), with an increased risk in the highest exposure group. But it should be noted that some of the studies included in Ahlbom *et al*. (2000) and Schüz and Ahlbom (2008) were identical; therefore, their results are not independent. In contrast to long-term measurements, a subgroup analysis of systematic reviews using calculated ELF MF exposure showed no dose–response patterns in their risk estimates (Ahlbom *et al*., 2000; Kheifets *et al*., 2010; Amoon *et al*., 2018, 2020; Brabant *et al*., 2022). Another observation is that the risk of childhood leukaemia has decreased over time (Swanson *et al*., 2019). A subgroup analysis of three independent pooled studies (Ahlbom *et al*., 2000; Kheifets *et al*., 2010; Amoon *et al.*, 2022) covering three non-overlapping time periods (< 2000, 2000–2010, 2010–2022) is shown in Figure 3.1. The figure displays the odds ratios (ORs) and 95% CIs from the individual studies, and also the overall risk estimates. Figure 3.1 suggests a decreasing trend over time, with the overall risk estimate approaching 1 (i.e. no risk). The hypothesis of a decrease over time was also tested in the review by Amoon *et al.* (2022) by analysing case–control studies based on the time of diagnosis of the leukaemia cases (Amoon *et al.*, 2022). The review found a non-statistically significant increased risk for the period 1953 to 1983 (OR 1.54, 95% CI 0.38 to 6.28). For the period 1984 to 1994 the risk level decreased (OR 1.20, 95% CI 0.53 to 2.71), and for the period 1995 to 2010 it was less than 1 (OR 0.71, 95% CI 0.32 to 1.55). However, the review states that the earliest period suffered from small case numbers and that the results were imprecise. A temporal trend in selection bias may explain the observed pattern if not causal. The presence of unknown confounders is another possible explanation for inconsistent findings. Crespi *et al.* (2019) investigated whether the risk of childhood leukaemia is due to MF exposure alone or is due to a combination of factors, including MFs, distance to power lines and voltage (Crespi *et al.*, 2019). Using interaction analyses they found that neither distance to power line nor ELF MF exposure level alone predicted leukaemia risk. Elevated risks were found only in the group very close to high-voltage power lines (< 50 m) and with high calculated exposure levels (≥ 0.4 μT). However, high ELF MFs (≥ 0.4 μT) near low-voltage (< 200 kV) power lines were not associated with an elevated risk. This suggests that ELF MFs may not be the sole explanation for elevated risk, although a higher extent of exposure misclassification near low-voltage lines might also be an explanation for the absence of an association (Crespi *et al.*, 2019). There is a range of environmental exposures, including air pollution, pesticides and radiation, and also parental exposures before birth, that may be associated with childhood leukaemia and could be potential confounders for the association with ELF MFs (Buffler *et al.*, 2005). Although progress has been made in this field, further research is required to make any firm conclusions.

The majority of systematic reviews analysing the association between ELF MF exposure and cancers other than childhood leukaemia found no significant increase in risk. Only a systematic review by Zhang *et al.* (2016) found a statistically significant association between any cancer and residential exposure to ELF MFs in the general population (OR 1.18, 95% CI 1.02 to 1.37). However, when they restricted risk estimates to studies with direct measurement methods, they no longer found an increased risk.

The umbrella review identified two meta-analysis studies on the risk of ALS associated with public ELF MF exposure (Röösli and Jalilian, 2018; Filippini

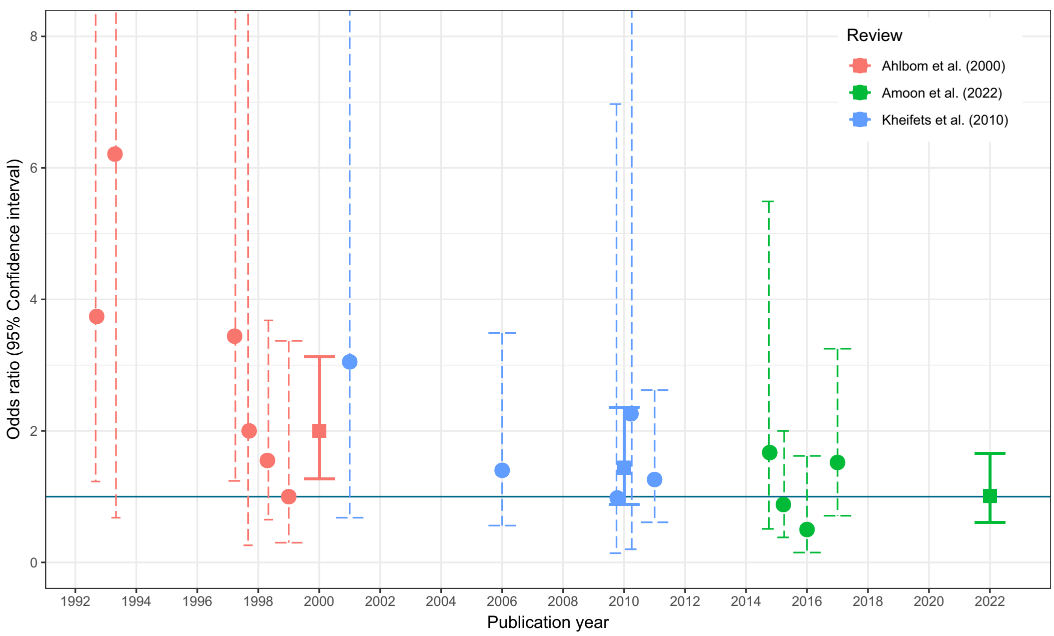

Figure 3.1. Scatterplot showing risk estimates over time. Points indicate ORs of individual studies included in the reviews listed in the legend. Squares indicate the pooled risk estimates.

et al., 2021) and one meta-analysis study on the risk of dementia associated with public ELF MF exposure (Zhao *et al*., 2021). Neither of these meta-analyses found a statistically significant risk among ELF MF-exposed subjects.

3.4 Systematic Review of Birth Outcomes and Fertility Potentially Associated with Public ELF EMF Exposure

3.4.1 Methods

The protocol for the systematic review has been published via OSF (https://osf.io/g3bew). In brief, three databases (Web of Science, PubMed, Embase) and the EMF-PORTAL (https://www.emf-portal.org/en) were systematically searched from 2015 to 2022. Keywords related to "exposure" ("magnetic field", "electric field", "extremely low frequency", "ELF", "electromagnetic field", "electrical substation", "power substation", "railway", "electric utility", "power plant", "electrical grid", "power line", "transmission line", "distribution line", "hybrid line", "HVDC", "HVAC" and "transformer") and "birth outcome" were used ("pregnancy", "birth weight", "gestational age", "pre-term birth", "preterm birth", "developmental disorder*", "birth defect*", "birth outcome*", "fetal growth", "foetal growth", "miscarriage", "abortion", "stillbirth", "congenital disorder*", "abortion" and "birthweight"). The title and abstract of identified papers were screened for eligibility; a list of eligibility criteria is provided in the protocol. From eligible papers the following data items were extracted: authors, publication year, country, time period, number of cases, covariates, study design, specific health outcome, source of health outcome data, the method of case ascertainment, source of exposure data, exposure assessment method, risk estimates [OR, risk ratio (RR), hazard ratio (HR) and 95% CI)]. The risk of bias in individual studies was assessed using a modified version of the method used by Repacholi (2012; Jalilian *et al*., 2018). This method considers seven sources of bias (funding source of study, reporting, data analysis, selection/participation bias, confounding, exposure assessment and outcome misclassification) and three weights: full additional weight (two stars), partial weight (one star) and no weight (no stars). The sum of stars indicates the total risk of bias in individual studies, with zero stars indicating the highest risk of bias and 14 stars indicating the lowest risk of bias.

3.4.2 Results

During the database searches, 339 unique papers were identified. After screening the titles and abstracts, 31 papers remained. After examination of the full texts, seven papers were included in the systematic review. A detailed flow diagram of the selection process is shown in the deliverable D3.1 report.

The literature search identified three cohort and four case–control studies on the association between birth outcomes and public exposure to ELF MFs (Table 3.1); these studies were conducted in Iran ($n=2$) (Sadeghi *et al*., 2017; Esmailzadeh *et al*., 2019), the USA ($n=2$) (Li *et al*., 2017; Ingle *et al*., 2020), Canada ($n=1$) (Auger *et al*., 2019), China ($n=1$) (Ren *et al*., 2019) and Finland ($n=1$) (Eskelinen *et al*., 2016). Power lines and transformers were the main sources of exposure. The exposure assessment methods were based on the distance to the source ($n=3$) (Sadeghi *et al*., 2017; Auger *et al*., 2019; Esmailzadeh *et al*., 2019) and direct measurement of ELF MFs ($n=4$) (Eskelinen *et al*., 2016; Li *et al*., 2017; Ren *et al*., 2019; Ingle *et al*., 2020). A wide range of outcomes were assessed, which were obtained from hospital ($n=5$) (Sadeghi *et al*., 2017; Auger *et al*., 2019; Eskelinen *et al*., 2016; Esmailzadeh *et al*., 2019; Ren *et al*., 2019) and medical records ($n=2$) (Li *et al*., 2017; Ingle *et al*., 2020). All studies considered numerous variables to control the effects of cofounders. A list of the publications included in the systematic review has been provided in D3.2, "Repository of epidemiological literature identified in the umbrella review and systematic review".

A case–control study in Iran by Esmailzadeh *et al*. (2019) observed a statistically significant OR of 4.44 (95% CI 2.77 to 7.11) for female infertility (defined as the failure to achieve pregnancy after 12 months or more of regular unprotected sexual intercourse) among women who lived within 500 m of a power line compared with those who lived >1000 m away (Esmailzadeh *et al*., 2019). However, the distance categories used in this study may have misclassified the exposure level. In general, ELF MF exposure is expected not to exceed the background level at 200 m distance from power lines (Vergara *et al*., 2015).

Pregnancy problems, including time to pregnancy, delayed pregnancy, total pregnancy loss, implantation, clinical pregnancy, live birth, total pregnancy loss, miscarriage and newborn death, were investigated in four studies (Eskelinen *et al*., 2016; Li *et al*., 2017;

Table 3.1. Characteristics of eligible observational studies on the association between ELF MF exposure and birth outcomes

Reference	Exposure source	Outcome	Risk estimate (95% CI)[a]
Cohort studies			
Eskelinen *et al.*, 2016	Built-in transformer and overhead and underground cables	Time to pregnancy	OR 0.41 (0.05 to 3.50)
		Delayed pregnancy	OR 1.05 (0.22 to 5.12)
		Small for gestational age	Not reported[b]
		Low birth weight	Not reported[b]
Li *et al.*, 2017	Not specified	Miscarriage	HR 2.02 (0.95 to 4.28)
Auger *et al.*, 2019	Power lines and transformer stations	Any birth defects:	
		• Power lines	RR 1.02 (1.00 to 1.03)
		• Transformer	RR 1.05 (1.00 to 1.09)
		Multiple birth defects:	
		• Power lines	RR 0.97 (0.91 to 1.04)
		• Transformer	RR 1.15 (0.98 to 1.35)
Case–control studies			
Sadeghi *et al.*, 2017	Power lines	Preterm births	OR 3.28 (1.37 to 7.85)
		Birth defects	OR 5.05 (1.52 to 16.78)
		Newborn death	OR 0.85 (0.09 to 7.75)
Esmailzadeh *et al.*, 2019	Power lines	Infertility (female)	OR 4.44 (2.77 to 7.11)
Ren *et al.*, 2019	Not specified	Birth weight; skinfold thickness of triceps, abdomen and back; and circumference of head, upper arm and abdomen	Not reported[b]
Ingle *et al.*, 2020	Not specified	Implantation	RR 0.85 (0.56 to 1.28)
		Clinical pregnancy	RR 0.84 (0.53 to 1.34)
		Live birth	RR 0.91 (0.56 to 1.49)
		Total pregnancy loss	RR 0.79 (0.45 to 1.38)

[a]Risk estimate (lower bounds and upper bounds of CI).
[b]Eskelinen *et al.* (2016) reported mean difference, and Ren *et al.* (2019) reported mean measured outcome.

Sadeghi *et al.*, 2017; Ingle *et al.*, 2020) among women exposed to ELF MFs within their homes. Three of these studies had a high quality score (Eskelinen *et al.*, 2016; Li *et al.*, 2017; Ingle *et al.*, 2020) and one study had a moderate quality score (Sadeghi *et al.*, 2017). None of the studies found a statistically significant association between pregnancy outcomes and ELF MF exposure.

Four studies examined a number of birth outcomes including small for gestational age, low birth weight, preterm births, fetal growth, any birth defect and multiple birth defects. Two studies, from Iran (Sadeghi *et al.*, 2017) and Canada (Auger *et al.*, 2019), with moderate or high quality scores, reported statistically significant risks for general birth outcomes and preterm births associated with residential distance to electricity infrastructure. The RRs for any birth defect reported in the Canadian study were 1.02 (95% CI 1.00 to 1.03) for people living < 200 m from a power line and 1.05 (95% CI 1.00 to 1.09) for people living < 200 m from a transformer station (Auger *et al.*, 2019). The Iranian study considered a distance of 600 m as the cut-off point for exposed subjects, and the OR was 3.28 (95% CI 1.37 to 7.85) for preterm births and 5.05 (95% CI 1.52 to 16.78) for birth defects (Sadeghi *et al.*, 2017). However, as mentioned above, a distance of 600 m is likely to result in exposure misclassification. The study by Ren *et al.* (2019) indicated that girls, but not boys, with higher prenatal ELF MF exposure had lower birth weights, lower triceps, abdomen and back skinfold thickness and smaller circumferences of head, upper arm and abdomen. The reviewed studies did not confirm an association between small gestational age, low birth weight (Eskelinen *et al.*, 2016) or multiple defects (Auger *et al.*, 2019) and ELF MF exposure.

4 Policies in EU Countries on ELF EMF Exposure

4.1 International Guidelines

The ICNIRP is an independent non-profit organisation that aims to develop and disseminate scientific advice on limiting exposure to non-ionising radiation. The ICNIRP consists of experts from different countries and disciplines, such as biology, epidemiology and physics, who assess risks related to non-ionising radiation exposure and provide guidance based on peer-reviewed scientific literature (ICNIRP, 2022). In 1998, the ICNIRP published its first comprehensive “Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 Ghz)” (ICNIRP, 1998). These guidelines were based on short-term, immediate health effects, such as the stimulation of peripheral nerves and muscles or shocks and burns caused by temperature increase, as evidence from long-term epidemiological and laboratory studies was considered insufficient to develop guidelines.

The guidelines provided two types of limits: basic restrictions and reference levels. Basic restrictions were based directly on established health effects associated with exposure to time-varying EMFs. The physical quantities used to specify basic restrictions were current density (*J*) and specific absorption rate (SAR), depending on the frequency and associated effects. Reference levels were provided for practical exposure assessment purposes. They were used to determine whether the basic restrictions are likely to be exceeded in a given exposure scenario. The reference levels were obtained from the basic restrictions through mathematical modelling and extrapolation from results of laboratory studies at specific frequencies. For ELF fields, the derived quantities for reference levels were electric field strength (*E*) expressed in volts per metre (V/m), magnetic field strength (*H*) expressed in amperes per meter (A/m) and magnetic flux density (*B*) expressed in tesla (T). The recommended reference levels for 50 Hz magnetic fields are shown in Table 4.1.

In 1999, the EU published the “Recommendation on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)” (EU, 1999).

Table 4.1. Reference exposure limits recommended by ICNIRP and the EU for 50 Hz magnetic fields

Organisation	Publication year	Magnetic flux density (μT)	Electric field (kV/m)
ICNIRP	1998	100	5
	2010	200	5
EU	1999	100	5
	2009	100	5

The EU Recommendation was based on the numerical values provided by the ICNIRP in 1998, and the reference levels at 50 Hz were identical to those in the 1998 ICNIRP guidelines (Table 4.1).

In 2010, the ICNIRP published a revised version of its guidelines for low-frequency EMFs entitled “Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz)” (ICNIRP, 2010). Similarly to the 1998 guidelines, the ICNIRP provided revised basic restrictions and reference levels. However, in the 2010 guidelines the physical quantity used to specify the basic restrictions was internal electric field strength, rather than current density, to address acute risks related to transient nervous system responses, the induction of retinal phosphenes and potential effects on brain function. The reference levels in the 2010 guidelines were obtained from the basic restrictions via mathematical modelling using published data (Dimbylow, 2005). They were calculated for the condition of maximum coupling to provide maximum protection, and they took into account frequency dependence and dosimetric uncertainties. The revised ICNIRP 2010 reference levels are shown in Table 4.1.

However, the EU did not update its guidelines and instead reconfirmed the 1999 Recommendation in 2009 (European Parliament, 2009) (Table 4.1). This decision was based on reports made to the European Parliament, which highlighted the growth in a wide range of EMF sources and the ongoing debate within the scientific community regarding potential health risks (Commission of the European Communities, 2008; The Committee on the Environment, 2008; European Parliament, 2009).

4.2 EMF Guidelines in EU Countries

The EU 1999 Recommendations were not legally binding, and their implementation into national policies of EU Member States varies. Broadly speaking, EU Member States have used three different approaches (Stam, 2018):

1. The EU Recommendation has been transposed into binding national legislation or national policy, which means that the basic restrictions and reference levels must be applied. *Countries: Czechia, Estonia, France, Germany, Greece, Hungary, Ireland, Luxembourg, Portugal, Romania, Slovakia*.
2. The national limits based on the EU Recommendation or the ICNIRP are not binding, there are more lenient limits or there is no regulation. *Countries: Austria, Cyprus, Denmark, Finland, Iceland, Latvia, Malta, Monaco, Netherlands*, *Norway, Sweden, Spain, UK*.
3. Member States use stricter basic restrictions and/or reference levels, based on the precautionary principle or owing to public pressure. *Countries: Belgium, Bulgaria, Croatia, Italy, Lithuania, Poland, Switzerland, Serbia, Slovenia.*

Although Ireland is listed in the first group, it has not transposed the EU 1999 Recommendation into national law, but these limits are commonly applied, following best practice. Some EU countries use additional precautionary measures to limit ELF EMF exposure, particularly children's exposure. The precautionary measures used vary from country to country; however, in several countries that are part of group 1 or group 2, precautionary policies are in place in addition to the existing national policies. The precautionary policy is often based on advice from the government, and in some cases was voluntarily agreed by the electricity sector. In some countries the precautionary policy derives from a requirement in the law not for a specific limit value, but to minimise public exposure as far as possible within a reasonable cost (Stam, 2018). Descriptions of the precautionary policies in each country are listed in Table 2 in the deliverable D4.1 report. An example of a precautionary policy used in the Netherlands is to avoid creating locations along new power lines where children are exposed to an annual average MF level of $>0.4\,\mu T$. The same policy is applied to new apartments or schools close to existing high-voltage power lines. Another example is precautionary measures that have been included in Italian law, which set an "attention value" of $10\,\mu T$ (24 h median) that should not be exceeded in residences, schools and places where people spend more than 4 hours per day. In addition, there is a "quality objective" for the construction of new power lines and the construction of new settlements near existing power lines. The aim of the quality objective is to progressively minimise MF exposure of the public to a median 24 h value of $3\,\mu T$, which should not be exceeded in residences, schools and places where people spend more than 4 hours per day.

4.3 ELF MF Monitoring Strategies

A review on the state of EMF exposure monitoring activities in Europe (Dürrenberger *et al.*, 2014) concluded that systematic and co-ordinated efforts to monitor EMFs were rare, particularly for ELF EMFs. This review found that only Cyprus, Hungary and Slovenia were carrying out annual surveys with a large sample size. Austria, Finland, France, Greece, Ireland, the Netherlands, Norway, Slovakia, Switzerland and the UK were found to carry out ad hoc surveys with small sample sizes, while the remaining European countries were reported to carry out no monitoring or did not specify any monitoring activities. In addition, only Austria, Finland, the Netherlands, Slovakia and Switzerland reported modelling or calculations of ELF EMF.

A targeted search in a selection of European countries showed that currently there are ongoing monitoring programmes in Ireland, Germany and Switzerland that are aiming to assess ELF EMF exposure in the general population. In Cyprus and Italy there are annual short monitoring surveys of ELF EMFs near electricity infrastructure. The results from these short surveys are published via websites (Cyprus: https://fosscy.eu/projects/emfmap/index.php; Italy: https://annuario.isprambiente.it/sys_ind/935). In France, a control and monitoring system was established in 2012 that required measurements at 5000 locations between 2012 and 2017. Measurement point locations were based on the presence of residential buildings near high-voltage lines and were selected so that the maximum exposure would be captured. All of the established measurement points must be reassessed every 10 years. The results of the measurement surveys are made publicly available via an interactive map: https://www.cem-mesures.fr/. In addition to the surveys required via the control and measurement system, the mayors of French municipalities can request an EMF field survey in response to concerns raised by local citizens. Surveys can be requested only for 400 kV transmission lines and transmission lines with a rated current greater than 400 A. In Slovenia, ELF EMF surveys are required for new and reconstructed sources of EMFs in sensitive use areas, and operational monitoring surveys have to be repeated every 5 years.

4.4 Methods to Reduce ELF EMF Exposure

Electric fields can be shielded near their source using a conducting enclosure, such as a Faraday cage. In practice, most materials, including building materials, will shield EFs; therefore, ELF EF from powerlines is rarely measured inside houses. In contrast, MFs are not affected by the human body or easily blocked by objects, and the permeability of the body and of most materials is the same as the permeability of air. This means that exposure reduction of MFs is more difficult. Methods to reduce ELF MF exposure from electricity infrastructure can be divided into two groups: intrinsic and extrinsic techniques (Bravo-Rodríguez *et al*., 2019).

Intrinsic techniques are methods that change electrical and/or geometrical parameters of the MF source, and thereby reduce the magnetic flux density level. The most commonly used methods in this group are compacting the power lines by changing the relative positions of the conductors, increasing the distance to the source, phase splitting and phase separation. Increasing the distance to the source can involve increasing the height above or depth below ground of power lines. It can also involve increasing the horizontal distance between the source and the exposed subject. This solution creates “buffer” zones around electricity infrastructure. Minimal distances have been included in the legislation or precautionary policies of several countries. For example, in Italy a decree was passed in 2008 (Ministero dell’ambiente e della tutela del territorio e del mare, 2008) that specifies a calculation method for buffer zones around power lines to provide a safe distance. The calculation depends on the geometric arrangement of the conductors, the height above ground and the electric current. In Switzerland, the MF needs to be calculated for areas surrounding new power lines or for modifications to existing power lines prior to planning approval. For 380 kV power lines typically clearance areas of 60–80 m are required, and for 50 kV power lines the clearance distance is 15–25 m (Nationalrat Schweiz, 2015). If the magnetic field calculations show that the magnetic field will exceed 1 μT, mitigating actions must be taken to reduce exposure. These actions can be in the form of changes to the planned route of the power line or by using taller masts. In exceptional cases, authorities can grant an exceedance (Nationalrat Schweiz, 2015).

In extrinsic techniques additional equipment, called the mitigation system, is placed near the ELF EMF source or near the area that needs to be protected (Bravo-Rodríguez *et al*., 2019). Extrinsic techniques are divided into active techniques, i.e. techniques that require an external power source, and passive techniques. An example of a passive technique is the use of ferromagnetic materials to move MF lines away from an area that needs to be protected. In active techniques an external power source is used to inject appropriate currents (magnitude and phase) into a mitigation system. These currents generate a new MF, which partially cancels out the original field from the source. Because the current can be controlled, active techniques can provide a larger mitigating effect.

5 Communication of Risks Associated with ELF EMF Exposure from Electricity Infrastructure

5.1 General Concepts of Risk Communication in Environmental Health

In 2021 the World Health Organization (WHO) published a report titled “Effective risk communication for environment and health” (WHO, 2021), which outlined theories and concepts of risk communication in the field of environmental health and provided a list of good practices for effective risk communication. WHO defines risk communication as an “exchange of information, advice and opinions between experts or officials and people who face a threat (hazard) to their survival, health or economic or social wellbeing” (WHO, 2021). The aim of risk communication is to enable individuals to make informed decisions on potential hazards and if necessary to take protective actions. It is important to note that effective risk communication is a multifaceted process that goes beyond merely distributing facts.

Key elements of risk communication are building and maintaining trust, understanding risk perception and communicating complexity and uncertainty. Building trust with the public and stakeholders is essential for effective risk communication in environmental health. Trust can be divided into six components: perceived competency, objectivity, fairness, consistency, sincerity, and faith or goodwill. Each of these components must be addressed to ensure that stakeholders fully trust the risk communicator. Trust is not a static concept, but rather a dynamic process that requires an ongoing effort to maintain. Risk perception can be defined as an individual’s subjective assessment of the seriousness of a hazard and the associated risk (Gellman, 2020). The difference between a hazard and a risk can be defined as follows: a hazard is a substance, object or situation that has the inherent potential to cause harm, damage or injury; a risk is the likelihood or probability that harm, damage or injury will actually occur. Risk perception is influenced by a range of cognitive, emotional, experiential and sociocultural constraints, and these need to be taken into account in the risk communication process to ensure that messages resonate with the target audience. Uncertainty is an inherent component of risk communication. Uncertainty can arise from many sources, including scientific uncertainty about the risk itself, uncertainty about the potential impacts and consequences, and uncertainty about the effectiveness of risk management measures. Although uncertainty can lead to confusion, scepticism and misunderstandings among stakeholders, it has also been shown that being transparent and honest about scientific uncertainty does not necessarily undermine trust in facts or the risk communicator (WHO, 2021).

A common obstacle in risk communication is misinformation. Misinformation refers to the spread of false, inaccurate or misleading information about a risk, which can occur through a variety of channels, including social media and mainstream media. Misinformation can have significant negative impacts on risk communication: it can undermine public trust, it can lead to confusion and fear among stakeholders, and it can result in incorrect risk perceptions and inappropriate decision making. To address and prevent misinformation, it is important for risk communicators to proactively provide accurate and credible information, and to engage with stakeholders from an early stage in an ongoing dialogue about the risk.

5.2 Risk Communication in Electricity Infrastructure Projects

A search of the peer-reviewed literature identified relatively few studies that analysed risk communication on ELF EMF-associated electricity infrastructure projects. However, a study analysing general areas of public concern associated with electricity infrastructure found that health risks from EMF exposure are ranked as the most important perceived impact (Elliott and Wadley, 2012), which suggests that more research should be focused on risk communication on this topic. The papers identified in the literature search broadly addressed two aspects of risk communication: risk perception and uncertainty. Several studies found that electricity infrastructure, such as high-voltage power lines, is perceived as a risk to health by the public

(Buijs *et al.*, 2011; Papacostas, 2012; Zaunbrecher *et al.*, 2015). It was also found that citizens with perceptions of higher risk were more likely to seek further information and to join a citizens' initiative (Mueller *et al.*, 2017). A study in the UK showed that health impacts were the highest perceived risk from high-voltage power lines, but also that study participants perceived distance of homes and schools to power lines as a critical factor (Cotton and Devine-Wright, 2013).

Risk communication guidelines usually recommend communicating uncertainties in risk estimates to the public. However, the effectiveness of communicating uncertainties is often unknown. A recent study in Germany explored the effects of communicating uncertainty using the example of potential health risks associated with exposure to EMFs from power lines (Wiedemann *et al.*, 2021). Using a 2 × 2 factorial between-subjects design, no statistically significant differences in text understandability, clarity of risk information, doubts in the professional competence of the experts, risk perception or fear arousal were found between groups that received uncertainty information versus no uncertainty information, and between groups that received an explanation of uncertainty versus no explanation (Wiedemann *et al.*, 2021). This suggests that providing uncertainty information has little impact; however, the authors caution that uncertainty information can have both positive and negative effects. This advice is supported by findings from a study in the Netherlands, which showed that perceived inconsistencies in messages on uncertainties in health impacts increased public health concerns (Porsius *et al.*, 2016). This study also found that risk communication of precautionary measures increased risk perceptions and concerns (Porsius *et al.*, 2016). Study participants reported a gap between the information they received and the information they desired. The authors concluded that it is important to customise risk communication based on the specific needs of the target audience (Porsius *et al.*, 2016). An assessment of Dutch EMF information needs also observed that the most critical aspect of EMF risk communication is the clear and concise communication of the current scientific uncertainty regarding the health risks posed by EMFs (Claassen *et al.*, 2016).

5.3 Example of a Risk Communication Research Programme

In 2017 the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz) in Germany funded a national research programme on the expansion of the German high-voltage power grid (Stromnetzausbau) (Bundesamt für Strahlenschutz, 2017a). One theme of this research programme was risk perception and risk communication (Bundesamt für Strahlenschutz, 2017b), which aimed to determine German citizens' knowledge and risk perception of issues associated with the expansion of the power grid, and also their need for information. A further objective was to identify factors that influence public opinion formation, and the credibility of and confidence in the authorities. Under the risk perception and risk communication theme seven projects were funded (Bundesamt für Strahlenschutz, 2017b). Five of these projects have been completed or partially completed. The following paragraphs will highlight some of the methods used in these projects and the insights that they provided.

One project involved the organisation of two large workshops to enable an expert discussion between scientists, public authorities, citizens' initiatives and electrical grid operators. The expert discussion exposed environmental and social justice issues, as residents who were directly affected by planned new or upgraded high-voltage overhead lines perceived these as "socially unfairly distributed". Like the studies in the Netherlands, it was found that providing information about scientific uncertainties in risk assessments can increase concerns about potential health risks among the population. Furthermore, pilot projects were perceived as having a high degree of uncertainty, and residents reported feeling like "objects of investigation". The style and format of risk communication was also discussed, with a preference for small, topic-specific information stands rather than large lecture-style events. Consistency in messages and languages was found to be important to build public trust. A uniform language and clear explanations of technical terms need to be used during public events, particularly when complex topics such as measurement results, uncertainty and precautionary principles need to be addressed. Overall, it was decided that there is no "typical" risk communication, and that the communication process needs to be tailored to the specific circumstances of each electricity infrastructure development project.

Another project used a population-wide survey and an in-depth survey of residents living near power lines to determine public concerns regarding the expansion of the power grid. In contrast to previous studies (see section 5.2), responses showed that the visual impact of the power line was greater than the health impact, and that health issues, such as headaches, were mostly attributed to RF EMFs. In comparison with other potential health hazards, the fields generated by high-voltage power lines were perceived as a relatively low risk. The responses also revealed a misconception of exposure patterns, as participants felt less affected by MFs from household appliances than from high-voltage power lines. One-quarter of the respondents reported feeling well to very well informed on MFs near power lines. There was, however, a desire for more information regarding health risks, precautionary measures and recommended limit values.

An important project within this research programme focused on the presentation methods and formats used to present MF measurements to the public. The project compared three presentation formats: (1) a video, (2) a numerical infographic with explanatory text and (3) an explanatory graphic with images and text. It also compared three methods to contextualise MF measurement levels: (1) the ratio of the measured value to the limit value, (2) the ratio of the value at maximum system utilisation relative to the limit value and the measured value and (3) the ratio of the measured value relative to a typical household appliance, i.e. a vacuum cleaner. Using 274 study participants to rate the presentation formats, no statistically significant difference was found in terms of information clarity, usefulness, credibility and complexity. However, risk perceptions decreased after watching the video or looking at the explanatory graphic but stayed the same after looking at the numerical infographic. The study participants also rated the three methods to contextualise MF measurement levels. All three methods were rated positively, but participants rated the ratio of the measured value to the limit value and the ratio of the maximum system utilisation to the measured value higher than the comparison to household appliances. Irrespective of the presentation format and the contextualisation, the communication of the measured MF value itself resulted in a statistically significant decrease in risk perception within the study participants.

The research programme also included a project that carried out a comprehensive evaluation of the information materials provided via the Bundesamt für Strahlenschutz website. The materials were analysed using a range of methods including readability tools, public and expert workshops, expert and population-wide surveys, and focus groups. Based on their analyses, the researchers provided a number of recommendations to improve the materials. They recommended making the user guidance on each webpage more consistent and to improve navigation between webpages. There should be a clear outline and structure at the beginning of articles. Sources should be provided for each article, and they need to be clearly distinguished from further or supplementary materials. Graphics in articles should be linked to the text, i.e. the text should contain an explanation or reference to the graphic. An effort should be made to regularly update webpages to ensure that their contents and references are current. The researchers also recommended that separate materials be created for experts and lay people.

6 Recommendations

Based on the literature reviewed during this project on the topics of ELF EMF exposure, health impacts, policies and risk communication, the objective of this chapter is to provide recommendations for practices and future research in Ireland. The recommendations presented here are grouped into four subtopics.

6.1 Reference Level and Precautionary Policies

- It is recommend that Ireland, as an EU Member State, follows the recommendations of the EU (EU, 1999; European Parliament, 2009) and implements a reference level of 100 μT for ELF MFs and 5 kV/m for ELF EF for a frequency of 50 Hz.
- In addition, similarly to the Netherlands, consideration should be given to the introduction of precautionary policies for the construction of new high-voltage (i.e. ≥220 kV) electricity infrastructure in Ireland and the construction of new buildings.
  - If new high-voltage electricity infrastructure is being built near areas or buildings where people spend a significant amount of time, e.g. residences, schools, hospitals or childcare facilities, the background annual average exposure to ELF MFs at 50 Hz should not exceed 0.4 μT.
  - If new buildings in which people will spend a significant amount of time are being constructed near existing high-voltage electricity infrastructure, the background annual average exposure to ELF MFs at 50 Hz should not exceed 0.4 μT.
- If an impact assessment prior to construction indicates that the background annual average exposure to ELF MFs at 50 Hz will exceed 0.4 μT, additional mitigation measures should be considered. These could include relocating the planned electricity infrastructure or the building to increase the distance to the source of exposure (see section 4.4). In the case of overhead power lines, measures such as optimisation of the wiring of high-voltage lines in terms of phase, current direction and distance between wires to maximise the compensation of fields or moving cables underground could also be considered.

6.2 Regulatory Monitoring

- After the construction of new high-voltage (i.e. ≥220 kV) electricity infrastructure a fixed-location or spot monitoring survey should be carried out to determine the magnetic and electric fields at distances of 0 m, 5 m, 10 m, 15 m, 20 m, 25 m, 50 m, 75 m and 100 m from the source. This type of survey should be repeated every 10 years.
- The same type of survey measurements should be carried out when existing high-voltage electricity infrastructure is being modified or when the voltage or current is changed for a prolonged period of time.
- If new buildings are constructed in close vicinity to existing high-voltage electricity infrastructure, a fixed-location monitoring survey should be carried out indoors to ensure that indoor MF levels comply with the reference level (section 6.1) and if applicable with the precautionary policy.
- The results of the above monitoring surveys should be made publicly available through reports, an online map (comparable to the system used in France) and summary statistics (comparable to the system used in Italy).

6.3 Risk Communication

- It is recommended that a process, similar to the agreement with mayors in France, whereby local authorities can request an ELF EMF field survey if there is significant public concern, be introduced. This survey should be followed by a public information event that presents and explains the findings of the survey.
- It is recommended that a research programme is carried out to evaluate the information materials on ELF EMFs currently provided by the EPA. This research could involve workshops, focus groups and surveys, and also observational analyses of public events. This research programme should

also include an assessment of the knowledge and risk perceptions of the public before and after reading the information material.

6.4 Research and Capacity Building

- To continue and progress the work started in this project, it is recommended that a scientific advisory group on non-ionising radiation be established in Ireland. The scientific advisory group will ensure that state-of-the-art knowledge and skills are available, and it will steer future research on non-ionising radiation within Ireland.
- To obtain an understanding of the population at risk of high ELF EMF exposure in Ireland, it is recommended that a geospatial research study is carried out to estimate the number of houses and number of people located within close proximity of high-voltage electricity infrastructure.
- This project found that no monitoring surveys of ELF EMFs associated with electricity interconnectors have been published in the peer-reviewed literature. To further scientific knowledge on this topic, it is recommended that monitoring is carried out at the converter station and above the HVDC cable of the Celtic Interconnector before and after construction.

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Abbreviations

AC	Alternating current
ALS	Amyotrophic lateral sclerosis
CI	Confidence interval
DC	Direct current
EF	Electric field
ELF	Extremely low frequency
EMF	Electromagnetic field
EPA	Environmental Protection Agency
EU	European Union
HR	Hazard ratio
HVDC	High-voltage direct current
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
MF	Magnetic field
OR	Odds ratio
RF	Radiofrequency
RR	Risk ratio
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
WHO	World Health Organization

An Ghníomhaireacht Um Chaomhnú Comhshaoil

Tá an GCC freagrach as an gcomhshaol a chosaint agus a fheabhsú, mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ar thionchar díobhálach na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialáil: Rialáil agus córais chomhlíonta comhshaoil éifeachtacha a chur i bhfeidhm, chun dea-thorthaí comhshaoil a bhaint amach agus díriú orthu siúd nach mbíonn ag cloí leo.

Eolas: Sonraí, eolas agus measúnú ardchaighdeáin, spriocdhírithe agus tráthúil a chur ar fáil i leith an chomhshaoil chun bonn eolais a chur faoin gcinnteoireacht.

Abhcóideacht: Ag obair le daoine eile ar son timpeallachta glaine, táirgiúla agus dea-chosanta agus ar son cleachtas inbhuanaithe i dtaobh an chomhshaoil.

I measc ár gcuid freagrachtaí tá:

Ceadúnú

> Gníomhaíochtaí tionscail, dramhaíola agus stórála peitril ar scála mór;
> Sceitheadh fuíolluisce uirbigh;
> Úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe;
> Foinsí radaíochta ianúcháin;
> Astaíochtaí gás ceaptha teasa ó thionscal agus ón eitlíocht trí Scéim an AE um Thrádáil Astaíochtaí.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

> Iniúchadh agus cigireacht ar shaoráidí a bhfuil ceadúnas acu ón GCC;
> Cur i bhfeidhm an dea-chleachtais a stiúradh i ngníomhaíochtaí agus i saoráidí rialáilte;
> Maoirseacht a dhéanamh ar fhreagrachtaí an údaráis áitiúil as cosaint an chomhshaoil;
> Caighdeán an uisce óil phoiblí a rialáil agus údaruithe um sceitheadh fuíolluisce uirbigh a fhorfheidhmiú
> Caighdeán an uisce óil phoiblí agus phríobháidigh a mheasúnú agus tuairisciú air;
> Comhordú a dhéanamh ar líonra d'eagraíochtaí seirbhíse poiblí chun tacú le gníomhú i gcoinne coireachta comhshaoil;
> An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Dramhaíola agus Ceimiceáin sa Chomhshaol

> Rialacháin dramhaíola a chur i bhfeidhm agus a fhorfheidhmiú lena n-áirítear saincheisteanna forfheidhmithe náisiúnta;
> Staitisticí dramhaíola náisiúnta a ullmhú agus a fhoilsiú chomh maith leis an bPlean Náisiúnta um Bainistíocht Dramhaíola Guaisí;
> An Clár Náisiúnta um Chosc Dramhaíola a fhorbairt agus a chur i bhfeidhm;
> Reachtaíocht ar rialú ceimiceán sa timpeallacht a chur i bhfeidhm agus tuairisciú ar an reachtaíocht sin.

Bainistíocht Uisce

> Plé le struchtúir náisiúnta agus réigiúnacha rialachais agus oibriúcháin chun an Chreat-treoir Uisce a chur i bhfeidhm;
> Monatóireacht, measúnú agus tuairisciú a dhéanamh ar chaighdeán aibhneacha, lochanna, uiscí idirchreasa agus cósta, uiscí snámha agus screamhuisce chomh maith le tomhas ar leibhéil uisce agus sreabhadh abhann.

Eolaíocht Aeráide & Athrú Aeráide

> Fardail agus réamh-mheastacháin a fhoilsiú um astaíochtaí gás ceaptha teasa na hÉireann;
> Rúnaíocht a chur ar fáil don Chomhairle Chomhairleach ar Athrú Aeráide agus tacaíocht a thabhairt don Idirphlé Náisiúnta ar Ghníomhú ar son na hAeráide;
> Tacú le gníomhaíochtaí forbartha Náisiúnta, AE agus NA um Eolaíocht agus Beartas Aeráide.

Monatóireacht & Measúnú ar an gComhshaol

> Córais náisiúnta um monatóireacht an chomhshaoil a cheapadh agus a chur i bhfeidhm: teicneolaíocht, bainistíocht sonraí, anailís agus réamhaisnéisiú;
> Tuairiscí ar Staid Thimpeallacht na hÉireann agus ar Tháscairí a chur ar fáil;
> Monatóireacht a dhéanamh ar chaighdeán an aeir agus Treoir an AE i leith Aeir Ghlain don Eoraip a chur i bhfeidhm chomh maith leis an gCoinbhinsiún ar Aerthruailliú Fadraoin Trasteorann, agus an Treoir i leith na Teorann Náisiúnta Astaíochtaí;
> Maoirseacht a dhéanamh ar chur i bhfeidhm na Treorach i leith Torainn Timpeallachta;
> Measúnú a dhéanamh ar thionchar pleananna agus clár beartaithe ar chomhshaol na hÉireann.

Taighde agus Forbairt Comhshaoil

> Comhordú a dhéanamh ar ghníomhaíochtaí taighde comhshaoil agus iad a mhaoiniú chun brú a aithint, bonn eolais a chur faoin mbeartas agus réitigh a chur ar fáil;
> Comhoibriú le gníomhaíocht náisiúnta agus AE um thaighde comhshaoil.

Cosaint Raideolaíoch

> Monatóireacht a dhéanamh ar leibhéil radaíochta agus nochtadh an phobail do radaíocht ianúcháin agus do réimsí leictreamaighnéadacha a mheas;
> Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha;
> Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta;
> Sainseirbhísí um chosaint ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Ardú Feasachta agus Faisnéis Inrochtana

> Tuairisciú, comhairle agus treoir neamhspleách, fianaise-bhunaithe a chur ar fáil don Rialtas, don tionscal agus don phobal ar ábhair maidir le cosaint comhshaoil agus raideolaíoch;
> An nasc idir sláinte agus folláine, an geilleagar agus timpeallacht ghlan a chur chun cinn;
> Feasacht comhshaoil a chur chun cinn lena n-áirítear tacú le hiompraíocht um éifeachtúlacht acmhainní agus aistriú aeráide;
> Tástáil radóin a chur chun cinn i dtithe agus in ionaid oibre agus feabhsúchán a mholadh áit is gá.

Comhpháirtíocht agus Líonrú

> Oibriú le gníomhaireachtaí idirnáisiúnta agus náisiúnta, údaráis réigiúnacha agus áitiúla, eagraíochtaí neamhrialtais, comhlachtaí ionadaíocha agus ranna rialtais chun cosaint chomhshaoil agus raideolaíoch a chur ar fáil, chomh maith le taighde, comhordú agus cinnteoireacht bunaithe ar an eolaíocht.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an GCC á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóir. Déantar an obair ar fud cúig cinn d'Oifigí:

1. An Oifig um Inbhunaitheacht i leith Cúrsaí Comhshaoil
2. An Oifig Forfheidhmithe i leith Cúrsaí Comhshaoil
3. An Oifig um Fhianaise agus Measúnú
4. An Oifig um Chosaint ar Radaíocht agus Monatóireacht Comhshaoil
5. An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tugann coistí comhairleacha cabhair don Ghníomhaireacht agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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