11 POPULATION AND HUMAN HEALTH

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11 POPULATION AND HUMAN HEALTH

11.1 Introduction

The Proposed Development comprises of a 33 kV connection, c37.9 km in length, comprising c26.9 km of overhead line (OHL) and c11 km of underground cabling (UGC).

The OHL will comprise three conductors suspended from single wood poles and double wooden poles (H poles) supported by stays at points where the overhead line route changes direction or terminates. Each wooden pole will be stout with a 200 mm head diameter. The pole heights will range from 11-20 m, with the H pole consisting of two poles braced together 1.8 m apart and a steel cross arm supporting the 3 phase conductors.

The UGC will comprise of 3x240 mm^2 single core XLPE cables installed in 100 mm diameter ducts with an additional 100 m diameter duct also laid as a spare duct for communication links. The cable trench will be 500 mm wide by 1000 mm deep.

The new electricity grid infrastructure will use high-voltage alternating current (HVAC) technology at 50 Hz and will generate electric and magnetic fields (EMFs). The EMFs generated by this type of electricity transmission are often referred to as power frequency or extremely low frequency (ELF) EMFs. ELF EMFs are produced wherever electricity is generated, transmitted or used. Public exposure to ELF EMFs therefore comes from a wide range of sources in the human environment, alongside static electric and magnetic fields from the natural environment.

Full details of the Proposed Development, including a figure of the route for the proposed 33kV connection, are provided in Chapter 2 Project Description and Need.

The potential population and health effects associated with construction-related environmental health determinants have been inherently addressed via the relevant inter-related topic chapters. For example, Chapter 12 Air Quality and Chapter 14 Noise and Vibration assess to objective thresholds set to be protective of the environment and human health. Furthermore, for a development of this nature, EMF is the only relevant operational health determinant. On this basis, the purpose of this chapter of the ES is to provide an assessment of the ELF EMFs that would be generated by the Proposed Development during operation, giving maximum and typical field strengths to assess compliance with guidelines for public exposure to EMFs. It is not considered necessary to assess any other health determinants.

11.2 Consultation

As part of the consultation exercise for the EIA screening determination, DfI consulted both Derry City & Strabane Environmental Health Services (responses dated 19th May 2020 and 19th January 2021) and Fermanagh & Omagh Environmental Health Services (response dated 1st May 2020). Within their consultation responses, the Environmental Health Services of each Council stated that DfI should seek confirmation that the Proposed Development complies with the requirements of the electromagnetic fields public exposure guidelines of the Commission of Non-Ionising Radiation Protection (ICNIRP).

It can be confirmed that even when considering a worst case scenario, the Proposed Development does comply with the requirements of ICNIRP’s electromagnetic fields public exposure guidelines. Refer to Section 11.6 (Impact Assessment) of this chapter for more detail.

11.3 Approach and Structure

The approach to this assessment seeks to provide information regarding ELF EMFs, the scientific evidence base and the guideline exposure limits in place to protect health, in order to address potential public perception of risk in addition to showing compliance with those guidelines. The report structure is as follows:

- Remainder of this section – an introduction to EMFs;
- Section 11.4 – a summary of the health evidence base and view of health protection bodies;
- Section 11.5 – the guideline exposure standards set to protect health, with discussion of how these have been adopted in the UK and how they are applied;

- Section 11.6 – a conservative assessment of the maximum ELF EMFs that could be produced by the Proposed Development, showing compliance with the guideline public exposure standards; and
- Section 11.8 – a summary of effects, bringing together the assessment's findings.

11.3.1 Electric and Magnetic Fields

Electromagnetic fields and the electromagnetic forces they represent are a fundamental part of the physical world. Electromagnetic forces are partly responsible for the cohesion of material substances and they mediate processes of chemistry, including those in human cells. EMFs occur naturally within the human body (through nerve and muscle activity) and also exist in the form of the magnetic field created by the earth and electric fields in the atmosphere.

ELF EMFs are part of the electromagnetic spectrum, which also encompasses radio waves, microwaves, infrared, visible light, ultraviolet, x-rays and gamma rays. At higher frequencies, electric and magnetic fields are coupled together and referred to as electromagnetic fields; as the frequency decreases, the coupling decreases, and at the 50 Hz frequency used for HVAC electricity transmission, it is appropriate to think in terms of separate electric and magnetic fields.

Unlike ionizing radiation found in the upper part of the electromagnetic spectrum (such as gamma rays emitted by radioactive materials, or x-rays), ELF EMFs cannot break the bonds that hold molecules in cells together and therefore cannot directly produce ionisation that could be directly damaging to cellular material. This is why ELF EMFs are categorised as 'non-ionising radiation'.

EMFs are strongest close to the point at which they are generated (e.g. a current-carrying conductor) and decrease rapidly in strength with distance from the source.

11.3.1.1 Electric fields

Electric fields are created in spaces between points at different voltages. Voltage (potential difference) can be described as the pressure behind the flow of electricity, analogous to the pressure of water in a hose.

The static atmospheric electric field at ground level is normally about 100 volts per metre (V.m-1) in fine weather and may rise to many thousands of volts per metre during thunderstorms. Electricity in homes is at a voltage of 230 V but outside homes it is distributed and transmitted at higher voltages, from 400 V up to 400 kV in the UK.

Generally, the higher the voltage, the greater the electric field. However, electric fields are readily screened by metals, most building materials and a degree of screening is offered by trees, hedges, and other earthed objects. This means that underground cables do not produce an electric field above ground level due to being buried.

11.3.1.2 Magnetic fields

Magnetic fields are produced by current, which is the flow of electricity. Current can be likened to the volume of water flowing in a hose when the nozzle is open. Anything that uses or carries mains electricity is potentially a source of power frequency magnetic fields.

The strength of magnetic field from electrical equipment depends on the current carried by it, where generally, the greater the current, the greater the magnetic field. As such, magnetic fields come from a wide range of sources and vary significantly within households, workplaces and the built and natural environment.

Typical residential exposure to ELF magnetic fields is in the range of 0.01 μT to 0.2 μT [1]. Low-voltage distribution circuits, household wiring and electrical appliances are typically the main sources of residential exposure, although in some cases nearby high-voltage transmission can contribute to higher-than-average residential exposure [2]. Electrical appliances can sometimes generate significant ELF magnetic fields (shown in Table 11.1), albeit in close proximity and with exposure therefore typically of a short duration.

The time-varying magnetic field from AC mains electricity is separate to the Earth's natural (static) magnetic field, which varies between about 30 μT (microteslas) at the equator and 65 μT in high latitudes, being approximately 50 μT in Northern Ireland [3].

Table 11.1: Example magnetic fields from household appliances

Appliance	Magnetic field (μT)	Distance (cm)
Hair dryer	6 – 2,000	3
Vacuum cleaner	2 – 20	30
Microwave	4 – 8	30
Dishwasher	0.6 – 3	30
Television	0.01 – 0.15	100

Sources: World Health Organisation [4] (citing German Federal Office for Radiation Safety)

11.4 Health Evidence Base

11.4.1 Introduction

Electricity transmission and use is ubiquitous in the developed world, meaning that the entire population of a developed country such as Northern Ireland experiences ELF EMFs exposure in daily life. Strong ELF EMFs are known to interact with the human body, with detectible physiological effects. For these reasons, extensive scientific research has been undertaken, particularly over the last 40 years, into the potential for ELF EMFs exposure to cause adverse health effects. This research has formed the basis for health protection guidelines discussed in Section 11.5.

Scientific knowledge in this field is substantial, being based on a large number of epidemiological, animal and in-vitro studies. Reviews of this evidence base have been undertaken by a number of national and international health protection bodies over the course of the last decade, to summarise the findings of published research, form conclusions and give health protection advice (where applicable) based on the weight of evidence. Possible health outcomes ranging from reproductive defects to cardiovascular and neurodegenerative diseases have been examined but have not been substantiated [5, 6, 7, 8, 9, 10, 11].

These health protection bodies include: the World Health Organisation (WHO); the International Agency for Research on Cancer (IARC); the International Commission on Non-Ionizing Radiation (ICNIRP); the European Commission's former Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) (succeeded by the Scientific Committee on Health, Environmental and Emerging Risks); and in the UK the former National Radiological Protection Board (NRPB), later the Radiation Protection Division of the former Health Protection Agency (HPA), which in 2013 became part of the Centre for Radiation, Chemical and Environmental Hazards in Public Health England (PHE).

In Northern Ireland, neither the Department of Health, Social Services and Public Safety, the Public Health Agency, the DfI, the Northern Ireland Environment Agency nor the Health and Safety Executive for Northern Ireland publishes guidance or research concerning EMFs from electricity transmission. However, the former Department of Energy and Climate Change published a voluntary code of practice for demonstrating compliance with public exposure guidelines for EMFs which has been agreed by the Northern Ireland Executive, and is discussed in Section 11.5.

11.4.2 Reproductive, cardiovascular, and neurodegenerative disease and genotoxic effects

Initial research examining reproductive defects and exposure to ELF EMFs during pregnancy has focused mainly on the use of electric blankets and electrically heated beds. IARC concluded [12] in 2002 that there is little evidence to support an association of exposure to ELF EMFs with adverse reproductive outcomes. Reviewing further research since then (mainly cohort studies based on residential proximity to power lines), SCENIHR noted one study that indicated an association between foetal EMFs exposure and later development of asthma, but concluded that recent evidence does not show an effect on reproductive health [11]. ICNIRP state that since the publishing of their most recent guidelines in 2010, there have only been a few studies investigating reproductive health effects (primarily investigating maternal exposure and risk of miscarriage), none of which find evidence of adverse pregnancy outcomes [13].

WHO, ICNIRP and SCENIHR have reported [14, 8, 9] some evidence suggesting a possible link between ELF EMFs and certain neurodegenerative diseases, but consider the evidence at present inadequate to demonstrate this association and note that no biological mechanism for ELF EMFs exposure (at levels below guideline limits for public exposure) to cause neurodegenerative disease has been established.

A literature review article [15] published in 2012 regarding ELF EMFs and neurodegenerative disorders provided a good summary of the emerging evidence, particularly in relation to Alzheimer's disease, Parkinson's disease, Amyotrophic Lateral Sclerosis (ALS) and Huntingdon's disease. The review notes that this is a relatively novel area of research, and that fewer studies have been undertaken (mainly of occupational exposure), compared to studies of EMFs and cancer.

The evidence regarding whether ELF EMFs exposure is linked to, and a cause of, neurodegenerative disease is mixed. Epidemiological evidence correlates ELF EMFs exposure with Alzheimer's and ALS disease incidence. However, the evidence did not show a link with Parkinson's disease and Huntingdon's disease. The review notes that the epidemiological evidence in this area is limited by the fact that neurodegenerative diseases are not recorded in registries in the same way as cancers (making disease records less reliable) and that studies have generally not measured exposure but estimated it by occupation (e.g. power sector workers) or from interviews about daily activity.

Although possible causal mechanisms for neurodegenerative disease have been put forward, only limited experimentation in animals has been undertaken and the results have not supported these hypotheses. Research for Huntingdon's Disease involving studies on the brains of animals has shown evidence of a neuroprotective effect from EMF exposure.

A 2009 study in Switzerland [16] found an association between close residential proximity (<50 m) to high-voltage transmission infrastructure and risk of Alzheimer's disease based on death certificate data; however, a more recent study in Denmark using more robust data (based on Alzheimer's case diagnosis rather than death records) did not find an association [17]. A recent occupational exposure study of ALS found an association with ELF magnetic field exposure, identified by proxy using job categories [18]. However, a 2014 UK study of motor neurone disease, Alzheimer's disease and Parkinson's disease using the Central Electricity Generating Board (CEGB) cohort (with relatively detailed estimates of magnetic field exposure) did not find any statistically significant associations [19]. SCENIHR's most recent opinion is that the evidence since 2009 does not support a conclusion that ELF EMFs exposure increases Alzheimer's disease risk [11].

Both IARC and WHO consider the potential for an association between cardiovascular disease and ELF EMFs exposure to be speculative and weak, given the evidence [12, 14]. ICNIRP notes that heart muscle cells are less sensitive to direct stimulation than nerve tissue, and its public health protection guidelines are set on the basis of established effects that occur below the threshold at which direct nerve tissue or muscle tissue stimulation is possible. SCENIHR concluded in 2007 that *"An effect of heart rate variability seen in laboratory studies was the basis for a hypothesis that ELF [EMFs] exposure might affect the risk of cardiovascular disease and some initial epidemiologic results supported this. However, later well controlled studies have dismissed this hypothesis."* [20] (page 36) and in its 2009 opinion it did not find any evidence sufficient to change that conclusion, stating that an association between cardiovascular disease and ELF EMFs is "considered unlikely" [9] (page 43). This conclusion is supported by further heart disease studies from McNamee et al. [21, 22]. ICNIRP considers that there are convincing null findings regarding the association between ELF EMFs and cardiovascular disorders [13].

ELF EMFs are part of the non-ionising spectrum and as such do not have enough energy to cause direct damage to cell macromolecules leading to genotoxic effects through ionisation. Although there is little evidence of mutation directly caused by ELF magnetic fields, additional research has been recommended by WHO [14]. Similarly, a more recent evaluation of evidence from Maes & Verschaeve [23] states while many of the human cytogenetic biomonitoring studies conducted in the past showing predominantly positive results have clear shortcomings, the totality of the studies should not be disregarded.

Potential for ELF EMFs to cause cancer has been extensively studied. No causal link with cancers, such as adult leukaemia, brain tumours and breast cancer, has been established. Analysis has included studies of electricity workers with occupational exposure to ELF EMFs and adults and children with residential exposure. Pooled analyses (combining the results of multiple studies) and weight-of-evidence reviews have not found consistent epidemiological evidence of an association between ELF EMFs and adult leukaemia, or child or adult brain tumours, or a plausible biological mechanism for causation [12, 14, 24, 25].

A further concern has been whether there is potential for ELF EMFs exposure to indirectly increase breast cancer incidence through affecting melatonin production in the body. Melatonin may offer some protection against breast cancer development. A 2006 review of scientific studies by the former HPA [26] concluded that the evidence does not show that exposure to ELF EMFs affects melatonin levels or the risk of breast cancer. WHO goes further in concluding that the evidence is sufficient to give confidence that ELF magnetic fields do not cause breast cancer [14].

In 2002 IARC classified ELF magnetic fields as 'possibly carcinogenic to humans' on the basis of a possible link to childhood leukaemia at field strengths below the ICNIRP guideline public exposure limits. 'Possibly carcinogenic' is the lowest of three carcinogenicity classifications used by IARC ('carcinogenic', 'probably carcinogenic', and 'possibly carcinogenic'). To put this in context, this category presently has 315 other agents, including coffee and Aloe vera [1].

This classification was based on evidence that a correlation has been found between chronic exposure to weak ELF magnetic fields (at around 0.3–0.4 microtesla or greater) and an increased risk of childhood leukaemia. WHO and ICNIRP concluded that the results of pooled analyses [27, 28] for a number of international studies reduce the possibility that the correlation is due to chance, but do not rule out potential bias or confounding variables. The evidence base for a causal link between ELF EMFs and childhood leukaemia was and remains inconclusive, as despite extensive research, no plausible mechanism for a weak magnetic field to cause the disease has been established [13].

Additional research in the period since the 2007 WHO review has been carried out to further investigate the possibility of a causal link between ELF EMFs and childhood leukaemia. However, the evidence examined remains inconclusive: some evidence of a possible increase in childhood leukaemia risk at long-term magnetic field exposure, in the order of 0.3–0.4 μT, continues to support the IARC classification of ELF EMFs as a possible carcinogen (e.g. [24, 29, 30, 31], but again evidence of a causal relationship or a mechanism to explain causation has not been established. It is probable that this uncertainty will not be fully resolved, as even large epidemiological studies (of the type already conducted) lack the statistical power to identify weak effects on a small affected population with a high degree of confidence, in particular given study limitations in the area of estimating long-term exposure and linking this to particular ELF EMFs sources.

The largest series of studies of childhood cancer and ELF EMFs exposure has been undertaken by the Childhood Cancer Research Group at the University of Oxford, published in 2005, 2010 and 2014. The original study is sometimes referred to as the Draper study after the 2005 publication's lead author. The study in 2005 [32] initially found an association between childhood leukaemia and ELF EMFs exposure, based on residential distance from high-voltage power lines. However, a re-analysis in 2010 [33] to improve the study to use calculated magnetic field strength (rather than distance as a proxy for exposure) indicated that the initial distance-based finding of risk was implausible as it extended to a distance at which magnetic field strength would be negligible and below typical household background.

The study was extended again in 2014 [34] to add evidence from Scotland and for 132 kV overhead lines and to present trend in risk over time. This showed that the apparent elevated risk is greatest in earlier decades of the time period considered in the study (1962-2008), which suggests that a factor that changes over time (such as population characteristics) is more likely to be the explanation than a physical effect from power lines. The final re-analysis of the CCRG data published in 2018 [35] to look in more detail at distance categories did not find that risk was highest at the shortest distance from power lines where the magnetic or electric field strength is strongest.

A study in Denmark [36] designed using a comparable approach to the CCRG work, to provide independent verification of these findings, did not find an excess leukaemia risk for children living within 200 m or 600 m of high-voltage power lines. A third comparable study [37] to further extend this evidence has been undertaken in

[1] Coffee is classified as 'possibly carcinogenic to humans' as it may increase the risk of bladder cancer, while at the same time be protective against bowel cancer. Aloe vera has relatively recently been placed into this category based on intestinal cancer risk from ingestion and evidence of skin cancer risk from dermal application combined with sunlight exposure, based on mouse and rat studies.

California, and found a slight excess of childhood leukaemia cases within 50 m of a transmission line over 200 kV (albeit with a wide confidence interval), but no evidence of increased risk at distances beyond 50 m, for lower-voltage lines, or for cancers of the central nervous system [38]. A further pooled analysis of these and other studies, published in 2018 [39], found no statistically significant association between childhood leukaemia risk and distance to power lines. A possible "*small and imprecise risk*" for residing within 50 m distance of a ≥200 kV overhead line was noted but this did not correlate with calculated magnetic field strength.

Overall, the evidence reviewed above illustrates the difficulties of reliance on epidemiological evidence for a very small disease risk, and the importance of considering the overall weight of evidence including animal and human cell studies.

Key questions when considering mixed evidence regarding a possible health risk are whether there is a statistically significant and strong relationship between exposure and health effect; whether there is a dose-response relationship (greater effect with greater exposure); whether different types of evidence are consistent (epidemiological studies, studies in animals, studies in human cells); and whether it is biologically plausible that exposure could create the health effect [40, 41]. This is also emphasised in a May 2018 position statement from the Society for Radiological Protection on evaluating EMF research publications [42].

In the case of EMFs and childhood leukaemia, the statistical evidence of epidemiological studies is mixed; and although taken together may suggest a risk, it does not show a clear dose-response relationship across studies; very extensive studies in animals and human cells have not established a mechanism for low-strength magnetic fields to cause cancer; the existence of such a mechanism is considered biologically implausible; and strong alternative explanatory hypotheses have been put forward.

In particular, the longstanding 'Greaves hypothesis' that pre-birth and early childhood blood cell mutations (affected by genetic risk factors and lack of exposure to common microbial infections at the early stages of immune system development) cause a risk of acute lymphoblastic leukaemia development triggered by infections later in childhood has a good deal of evidential support, summarised in a review published in 2018 [43].

Nevertheless, as some evidence has suggested that there is a possible increase in risk of childhood leukaemia at long-term exposure to magnetic field strengths in the order of >0.3–0.4 µT, it could be argued that it may be appropriate to apply the precautionary principle and consider further intervention to reduce potential risk. A full discussion of this issue, which is a matter of national policy, is outside the scope of this document, but a paper published by Maslanyj *et al.* [44] gives a useful treatment of the position. The authors conclude that although there is *"no clear indication of harm at field levels implicated … the aetiology of childhood leukaemia is poorly understood. Taking a precautionary approach suggests that low-cost intervention to reduce exposure is appropriate. This assumes that if the risk is real, its impact is likely to be small. It also recognises the consequential cost of any major intervention. The recommendation is controversial in that other interpretations of the data are possible, and low-cost intervention may not fully alleviate the risk."* (page 8). The paper notes in particular that due to uncertainties in the evidence and the fact that they may not be resolved in the near future, *"despite the need for evidence-based policy making, many of the decisions remain value driven and therefore subjective"* (ibid).

The recommendation of a precautionary stance echoes WHO's 2007 view, which suggested that the use of *"suitable precautionary measures to reduce exposure is reasonable and warranted"* [14] (page 13) in view of uncertainties about the effects of chronic magnetic field exposure, but due to the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, the benefits of exposure reduction on health are unclear. WHO emphasised that any precautionary measures should not compromise the benefits of electric power and that the costs of any precautionary measures to further reduce exposure would only be justified where they are very low or have no cost.

The view of ICNIRP, expressed in the most recent guidelines for public exposure to low frequency time-varying fields, is that "*the currently existing evidence that prolonged exposure to low frequency magnetic fields is causally related with an increased risk of childhood leukaemia is too weak to form the basis of exposure guidelines*" [8] (page 2). In ICNIRPs recent review of gaps in the knowledge relevant to the 2010 guidelines (published in April 2020), it is acknowledged that as childhood leukaemia is a very rare disease, additional epidemiological studies of the same design are unlikely to advance knowledge as they will potentially be affected by the same types of biases as the existing studies [13]. Therefore, insight into potential biological mechanisms is required to improve assessment methods before results can be more heavily relied upon.

11.5 Public Exposure Guidelines

Health protection guidelines for public and occupational exposure to ELF EMFs were published by ICNIRP in 1998 [7] and 2010 [8]. These guidelines have been used in a number of sources of recommendations and advice on exposure to EMFs.

In the UK, the former HPA's Radiation Protection Division has recommended that the UK adopts the 1998 ICNIRP guidelines under the terms of the EC Recommendation. The Radiation Protection Division was formed in 2005 from the former National Radiological Protection Board (NRPB), which was the independent statutory body established to give advice on EMFs, including advice on safe levels of occupational and public EMFs exposure. In 2013 it became part of the Centre for Radiation, Chemical and Environmental Hazards in PHE. This recommendation is based on advice on limiting exposure to EMFs published by NRPB in 2004, following a review of the relevant scientific data [5, 6].

In 2004, following the NRPB's review of the scientific evidence, a Stakeholder Advisory Group on ELF EMFs (SAGE) was set up to consider whether any further precautionary measures, in addition to use of the ICNIRP guidelines, were warranted. SAGE was funded by the UK Government, electricity industry and a leukaemia charity and explicitly sought views from a wide range of stakeholders in an inclusive process. In 2007, SAGE's first interim assessment [46] made a series of recommendations for precautionary measures to further reduce public ELF EMFs exposure from high-voltage electricity transmission. These included optimal phasing for overhead power lines and implementing 'no-build corridors' around power lines.

The UK Government's response, published in 2009 [47], adopted the recommendation for optimal phasing for overhead lines but did not consider that no-build corridors were a proportionate precautionary measure, given the evidence base. This was based on the views of its scientific advisors and is in line with the WHO's 2007 recommendation that precautionary measures are only warranted where they are very low-cost or have no cost. SAGE has subsequently made further recommendations regarding household wiring and appliances.

Building on the outcomes of the SAGE process, in 2011 the former Department of Energy and Climate Change (DECC) published a voluntary Code of Practice (CoP) titled "Power Lines: Demonstrating compliance with EMF public exposure guidelines". This details the recommended approach for demonstrating compliance with adopted ELF EMFs exposure guidelines, subsequently updated in March 2012 [48]. The CoP "*has been developed following publication of the Government response to the Stakeholder Advisory Group on extremely low frequency electric and magnetic fields (ELF EMFs) (SAGE) First Interim Assessment…* [and] *agreed by the Department of Energy and Climate Change with the Department of Health, the Energy Networks Association, the Welsh Assembly, the Scottish Executive, the Northern Ireland Executive and the Health and Safety Executive*" (page 2). It implements the 1998 ICNIRP guidance for AC fields under the terms of the 1999 EC Recommendation, in the UK context.

A second Code of Practice [49], likewise arising from the SAGE recommendations and adopted by the Northern Ireland Executive, concerns implementing 'optimum phasing' of dual-circuit overhead lines where feasible. Transposing the order of phases can reduce the maximum field strength due to greater cancellation in the fields between the phases of each circuit.

A third Code of Practice [50] concerns measures to avoid microshocks, which can cause annoyance in some cases when touching ungrounded objects near power lines. This applies mainly to the highest voltage lines, of 275 kV and 400 kV, and the principal measure is to limit electric field strength to the reference level in the 1998 ICNIRP guidelines.

These Codes of Practice were adopted by the Northern Ireland Executive and the documents are published online for Northern Ireland by the Department for the Economy [51].

The Strategic Planning Policy Statement (SPPS) for Northern Ireland: Planning for Sustainable Development (2015) [52] states in paragraphs 6.249 and 6.250 that exposures to powerline EMFs and any proposals for new power line developments should comply with the 1998 ICNIRP guidelines. It refers to the optimum phasing and microshocks Codes of Practice although omits mention of the main 'Demonstrating Compliance' Code of Practice, which is presumably an unintentional oversight.

In this report, the main Code of Practice of relevance is the 2012 'Demonstrating Compliance' code, which is referred to as the CoP in the following sections.

The CoP states that the public exposure limit guideline values are for uniform, unperturbed fields near ground level, such as would be experienced from an overhead line. Although higher (less stringent) levels could be established on a case-by-case basis, the CoP states that the guideline levels would never be lower. As such, the guideline levels specified in the CoP are used as a conservative basis for the assessment in this report. The CoP specifies on page five that compliance of overhead lines and underground cables at voltages of >132 kV should be shown by *"a calculation or measurement of the maximum fields (i.e. directly under the line, or directly above the cable)"*. However, for all substations and for overhead lines or underground cables at ≤132 kV, the CoP states that compliance with the public exposure guidelines is assumed, based on evidence published by the Energy Networks Association (ENA) for types of infrastructure that by design are not capable of causing exceedance of the public exposure guideline limits.

The CoP specifies that, given the terms of the 1999 EC Recommendation, assessment of EMF exposure against the general public exposure guidelines is only required in general for residential exposure or certain other cases of long-term exposure of potentially vulnerable groups (e.g. schools). The CoP states that *"In other environments, where exposure can be deemed not to be for a significant period of time, the ICNIRP occupational guidelines, rather that the ICNIRP general public guidelines, shall be deemed to apply"* (page 4).

Public exposure to ELF EMFs from the Proposed Development will be both transient (e.g. on public footpaths or roads) and residential. Although the setting is rural, there is a total of 84 residential receptors within 100 m of the proposed route, which are depicted by pink and yellow dots in Figures 11.1 to 11.9, Volume II. To be conservative, ELF EMFs exposure from the Proposed Development has therefore been assessed against the general public (as opposed to occupational) exposure guideline.

Table 11.2 summarises the relevant exposure guidelines. The 'basic restriction' level to protect health is for induced current in the central nervous system. The reference level for external fields indicates a threshold beyond which the potential for induced current to exceed the 'basic restriction' should be investigated. Reference levels have been published by ICNIRP and by the former HPA. They relate to the same 'basic restriction' published by ICNIRP in 1998. The reference levels given in the CoP are those specified by the former HPA, on the basis of modelling undertaken by Dimbylow [53].

Table 11.2: ELF EMFs exposure guidelines adopted in the UK

Description		1998 ICNIRP guidelines, as adopted in the UK in the CoP	
		Occupational	**Public**
'Basic restriction' (the quantity that must not be exceeded)	Induced current density in the central nervous system	10 mA m^{-2}	2 mA m^{-2}
ICNIRP reference level (not a limit in itself but a guideline for when 'basic restriction' investigation may be required)	Magnetic field	500 μT	100 μT
	Electric field	10 kV m^{-1}	5 kV m^{-1}
CoP reference level (not a limit in itself but a guideline for when 'basic restriction' investigation may be required)	Magnetic field	1,800 μT	360 μT
	Electric field	46 kV m^{-1}	9 kV m^{-1}

Sources: ICNIRP [7] former DECC [48]

Although ICNIRP published updated guidance in 2010 [8] that gives a less stringent 200 μT reference level for general public magnetic field exposure, due to changes in the basis of the basic restriction, the 1999 EC recommendation for use of the more stringent 1998 ICNIRP guidance remains the basis of UK guidance and the CoP.

11.6 Assessment Methodology

The significance of an effect is determined based on the magnitude of an impact and the sensitivity of the receptor affected by the impact. This section describes the criteria applied in this chapter to characterise the magnitude of potential impacts and sensitivity of receptors.

11.6.1 Receptor Sensitivity

Within a defined population, individual sensitivity can vary due to a range of factors such as age, socio-economic deprivation and the prevalence of any pre-existing health conditions which could become exacerbated. These individuals can be considered particularly vulnerable to changes in environmental and socio-economic factors (both adversely and beneficially) whereby they could experience disproportionate effects when compared to the general population.

A precautionary approach has been applied, where it is assumed that the entire population within the study area are of uniformly high sensitivity in order to capture the most sensitive individuals within that population.

11.6.2 Magnitude of Impact

The criteria for defining magnitude in this chapter are outlined in Table 11.3.

Table 11.3: Definitions of Magnitude

Sensitivity	Typical Descriptors
High	Change in environmental or socio-economic factor sufficient to result in a major change in baseline population health or socio-economic circumstance (adverse or beneficial).
Medium	Change in environmental and socio-economic factor sufficient to result in a moderate change in baseline population health or socio-economic circumstance (adverse or beneficial).
Low	Change in environmental and socio-economic factor sufficient to result in a minor change in baseline population health or socio-economic circumstance (adverse or beneficial).
Negligible	Change in environmental and socio-economic factor below that for which it is possible to result in any manifest health outcome at a population level but may impact at an individual level (adverse or beneficial).

11.6.3 Significance of Effects

The significance of the effect has been determined by taking into account the sensitivity of the receptor and the magnitude of the impact. The method employed for this assessment is presented in Table 11.4. Where a range of significance levels are presented, the overall assessment for each effect is based upon evidence based expert judgement.

As previously noted, in all cases, a precautionary approach has been applied by applying a uniformly high receptor sensitivity and the evaluation is underpinned by narrative to explain the conclusions reached.

For the purpose of this assessment, any effects with a significance level of minor or less are not considered to be significant in terms of the EIA Regulations.

Table 11.4: Assessment Matrix

Sensitivity	Magnitude of Impact			
	Negligible	**Low**	**Medium**	**High**
Negligible	Negligible	Negligible or Minor	Negligible or Minor	Minor
Low	Negligible or Minor	Negligible or Minor	Minor	Minor or Moderate

Medium	Negligible or Minor	Minor	Moderate	Moderate or Major
High	Minor	Minor or Moderate	Moderate or Major	Major or Substantial

11.7 Impact Assessment

11.7.1 Introduction

The proposed transmission infrastructure development will comprise c26.9 km of 33 kV OHL and c11 km of 33 kV UGC.

The CoP states that compliance with the public exposure guidelines set to protect health is assumed for OHLs and UGCs operated at 132 kV or less, without the need for more detailed assessment, on the basis of evidence published by the ENA showing that by design such infrastructure is not capable of causing exceedance of the public exposure guideline limits.

The additional CoP concerning the optimum phasing of dual-circuit OHLs is not directly applicable to the Proposed Development, which comprises single-circuit overhead lines (i.e. three conductors).

The proposed route and all residential receptors located within 1 km from the centreline are shown in Figures 11.1 to 11.9, Volume II. Over the c37.9 km of route length, a total of 84 residential receptors are located within 100 m of the proposed route, 5 of which the route will pass either directly over or under.

11.7.2 33 kV Overhead Lines

The ENA's statement of exposure guideline compliance [54] is for large dual-circuit 132 kV OHLs. It states that the maximum magnetic field strength, calculated for 'worst case' conditions (i.e. with maximum load, minimum height clearance and untransposed phasing), is 40 μT, well below (11% of) the CoP 360 μT public exposure guideline limit set to protect health. The maximum calculated electric field strength is 3.6 $kV.m^{-1}$, well below (40% of) the CoP 9 $kV.m^{-1}$ public exposure guideline limit set to protect health.

The Proposed Development is for a single-circuit OHL at 33 kV, which would be expected to generate lower electric and magnetic field strengths for which the compliance information is provided.

Although compliance is shown for the largest dual circuit 132 kV design, the ENA also publishes further information concerning smaller single circuit 33 kV wooden pole design OHLs and small steel lattice pylon OHLs. Of the available evidence from the ENA, these examples are considered more representative of the Proposed Development's 33 kV OHLs on wooden poles. The maximum and typical electric and magnetic field strengths calculated are shown in Table 11.5 and Table 11.6. As described above, the ENA maximum field strengths are calculated for 'worst case' conditions. The ENA typical field strength is calculated for more usual operating conditions, and is significantly lower.

From the examples in Table 11.5 and Table 11.6, the maximum calculated electric field strength is 0.9 $kV.m^{-1}$, well below (10% of) the CoP 9 $kV.m^{-1}$ public exposure guideline limit set to protect health. The maximum calculated magnetic field strength is 25.7 μT, well below (7% of) the CoP 360 μT public exposure guideline limit set to protect health. The calculated field strengths under typical conditions are significantly lower again. The electric and magnetic field strength also decreases rapidly with distance from the OHL, as illustrated in Figure 11.10 and Figure 11.11. It should be noted that the typical electric field strength for 33 kV wood pole OHLs shows a slightly different relationship, whereby the typical electric field directly below the wood pole OHL is lower (83.7 V) than at c5 m away from the wood pole OHL, where the maximum of 241.4 V occurs, before returning down to 83.1 V at c14 m from the centreline. On this basis, the electric and magnetic field strength associated with the Proposed Development is compliant with the 1998 ICNIRP guidelines, as required by the SPPS for Northern Ireland.

As such, the magnitude of impact would be negligible, with no identifiable health effects even taking a precautionary approach of assuming uniformly high sensitivity across the entire population.

Table 11.5: Electric field strengths from 33 kV OHLs

CoP reference level: 9 kV.m^{-1} (equivalent to 9,000 V.m^{-1})								
	Maximum (33 kV steel pylon)		Typical (33 kV steel pylon)		Maximum (33 kV wood pole)		Typical (33 kV wood pole)	
Dist. (m)	V.m^{-1}	% of CoP ref. level	V.m^{-1}	% of CoP ref. level	V.m^{-1}	% of CoP ref. level	V.m^{-1}	% of CoP ref. level
Maximum under line	897	9.97%	543	6.03%	505	5.61%	241	2.68%
10	46	0.51%	81	0.90%	165	1.83%	147	1.63%
25	30	0.33%	21	0.23%	16	0.18%	21	0.23%
50	10	0.11%	9	0.10%	2	0.02%	3	0.03%
100	3	0.03%	3	0.03%	0	<0.01%	0	<0.01%

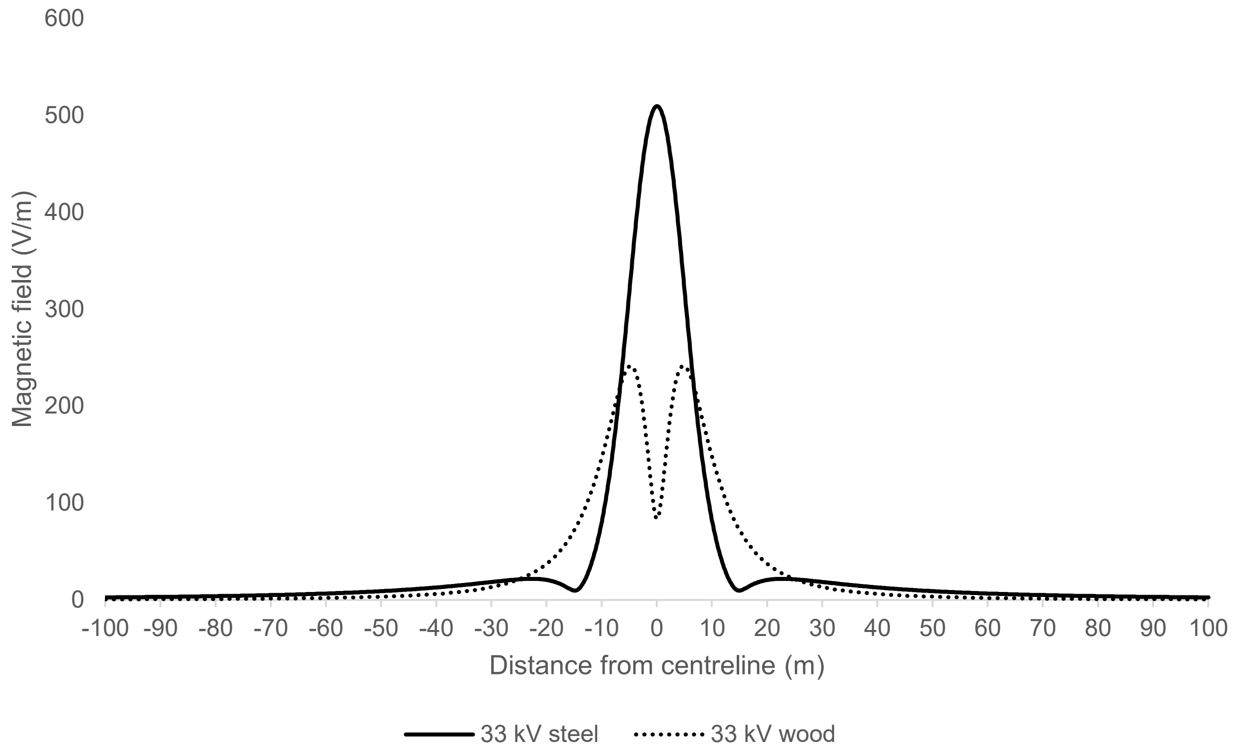
Note: The maximum under line value may be under a conductor rather than 0 m lateral distance from the centreline. Calculated field strengths are unperturbed at 1 m above ground level.
Sources: National Grid [55]

Table 11.6: Magnetic field strengths from 33 kV OHLs

CoP reference level: 360 μT								
	Maximum (33 kV steel pylon)		Typical (33 kV steel pylon)		Maximum (33 kV wood pole)		Typical (33 kV wood pole)	
Dist. (m)	μT	% of CoP ref. level	μT	% of CoP ref. level	μT	% of CoP ref. level	μT	% of CoP ref. level
Maximum under line	25.69	7.14%	1.56	0.43%	14.75	4.10%	1.33	0.37%
10	10.74	2.98%	0.82	0.23%	2.96	0.82%	0.47	0.13%
25	2.27	0.63%	0.21	0.06%	0.54	0.15%	0.10	0.03%
50	0.59	0.17%	0.06	0.02%	0.14	0.04%	0.03	0.01%
100	0.15	0.04%	0.02	<0.01%	0.04	0.01%	0.01	<0.01%

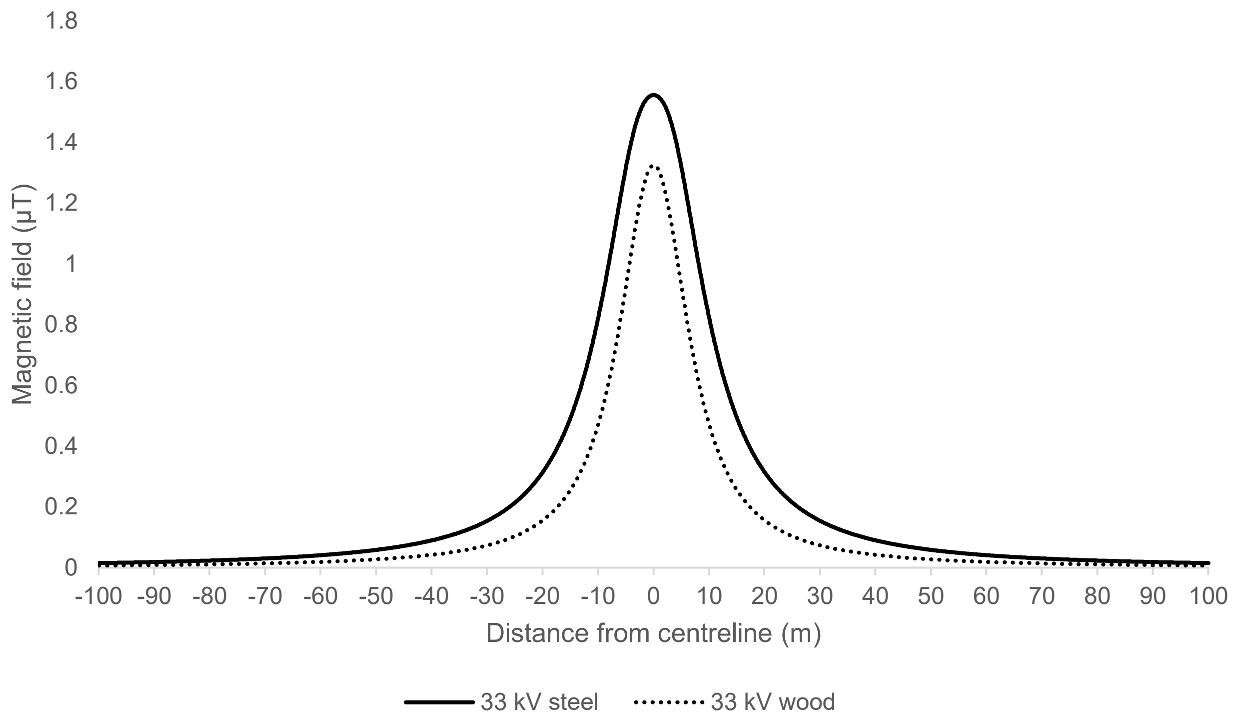
Note: The maximum under line value may be under a conductor rather than 0 m lateral distance from the centreline. Calculated field strengths are unperturbed at 1 m above ground level.
Sources: National Grid [55]

Figure 11.10: Typical electric field strengths by distance from 33 kV OHLs



Source: National Grid [56]

Figure 11.11: Typical magnetic field strengths by distance from 33 kV OHLs



Source: National Grid [56]

11.7.3 33 kV Underground Cables

Underground cables (UGCs) do not produce external electric fields because they are surrounded by a metal sheath which screens the electric field [54].

The Proposed Development is for a UGC rated at 33 kV and comprising three 240 mm^2 single core XLPE cables installed in 100 mm diameter ducts with an additional 100 mm diameter duct also laid as a spare duct for communication links. The cable trench is 500 mm wide by 1000 mm deep.

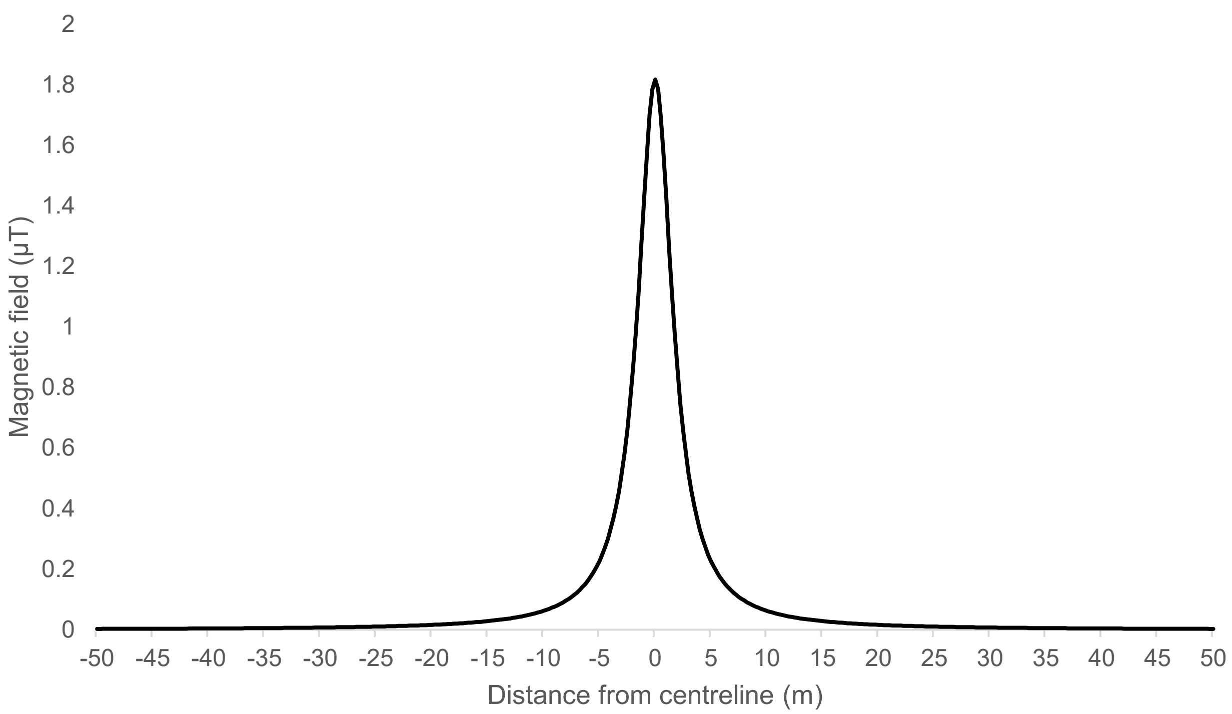
As stated by the ENA, a 33 kV cable with separate cores (as in this case) could be represented by a 132 kV cable with separate cores [55]. Based on a worst case hypothetical design (i.e. where 132 kV cores are separated by 1 m, buried 1 m below ground, and carry a load of 1000 A per phase), the magnetic field produced by the cable would comply with the CoP 360 μT public exposure guideline limit set to protect health [54]. On the basis that a 33 kV cable would produce a magnetic field lower than this, the proposed UGC would also be compliant by design.

While this is the case, calculations to estimate the potential magnetic field levels have been undertaken based on all possible options for cable phasing to provide further evidence of compliance.

NIE Networks has specified that to provide the proposed Curraghinalt Mine project with 12 MW of power, the cable will carry up to 262 A per phase. As shown in Figure 11.12, the calculated magnetic field produced by the cable would be 1.82 μT, which would occur at ground level directly above the centreline. This is well below (0.5% of) the Code of Practice 360 μT public exposure guideline limit set to protect health and would be compliant with the 1998 ICNIRP guidelines, as required by the SPPS for Northern Ireland.

As such, the magnitude of impact would be negligible, with no identifiable health effects even taking a precautionary approach of assuming uniformly high sensitivity across the entire population.

Figure 11.12: Calculated magnetic field strength by distance from 33 kV UGC



11.7.4 Inter-related and Transboundary Effects

As a continuation of the same proposed transmission infrastructure, there would be no additional inter-related population and human health effects associated with the interaction between the OHL and UGC which have not already been considered. Furthermore, on the basis that the proposed transmission infrastructure is located wholly within Northern Ireland (the UGC is approximately 1.5 km from the border and the OHL approximately 4 km from the border), there would be no transboundary population and human health effects.

11.7.5 Cumulative Effects

The Zone of Influence (ZoI) for potential cumulative human health effects is set at 1 km. This ZoI would capture any potential interaction between different environmental pollution sources on the basis that environmental health determinants typically have a local impact, where potential change in hazard exposure is limited by physical dispersion characteristics.

The most obvious development that has the potential for cumulative effects with the Proposed Development is the proposed Curraghinalt mine site. The proposed Curraghinalt mine site Health Impact Assessment (2017) reports no measurable adverse health impacts for any of the health determinants assessed (air quality, noise and vibration, transport, employment, surface water, groundwater and naturally occurring radioactive material).

The Proposed Development would connect to the electrical infrastructure at the proposed Curraghinalt mine site. However, on the basis that no adverse population and human health effects associated with ELF EMF are predicted for the Proposed Development and all electrical infrastructure at the proposed Curraghinalt mine site would also be compliant by design (i.e. ≤132 kV) no cumulative effects are likely.

The following other developments are located within 1 km of the Proposed Development, the closest of which is located approximately 200 m away:

- Industrial:
  - LA11/2018/0250/F – proposed light industrial building for the washing maintenance and refurbishment of formwork equipment used for concrete shuttering (238 m from the Proposed Development).
- Livestock and Poultry:
  - LA11/2017/0993/F – proposed free range poultry houses, max 32,000 birds with four meal bins and a litter shed (247 m from the Proposed Development).
- OHLs and Electrical Connections:
  - LA11/2016/0444/F – 11 kV three phase wooden pole power line (515 m from the Proposed Development).
- Wind Farms and Turbines:
  - LA10/2020/0512/F – proposed retention of an operational Vesta V52 wind turbine (60m hub height; 52m blade diameter 86m blade tip height) (200 m from the Proposed Development).
  - LA10/2018/0673/F – proposed erection of a 50m hub height Vesta V52 wind turbine with a max output of 225KW to replace wind turbine approval K/2012/0170/F (399 m from the Proposed Development).
- Waste Facilities and Wastewater Treatment Works:
  - LA11/2018/0463/F – replacement wastewater treatment plant within the existing site boundary (280 m from the Proposed Development).
  - LA11/2018/0724/F – extension to car parking area to include ramp GAS compound along with waste enclosure and associated perimeter fencing (767 m from the Proposed Development).

Where there is potential overlap between construction of the Proposed Development and construction activities associated with the other developments listed above, no cumulative effects are likely. This is on the basis that impacts associated with construction would be temporary and intermittent in nature and would therefore have limited potential to interact.

Furthermore, on the basis that no significant adverse population and human health effects are predicted for the Proposed Development and due to the separation distance between the Proposed Development and all other developments listed above, no cumulative effects are likely where operational activities would potentially overlap.

In relation to ELF EMF specifically, all other transmission infrastructure which has the potential to interact with the Proposed Development would be compliant by design. As such, no cumulative population and human health effects associated with potential exposure to ELF EMFs are likely.

11.7.6 Summary of Effects

The proposed electricity distribution infrastructure will comprise c26.9 km of 33 kV overhead line (OHL) and c11 km of 33 kV underground cabling (UGC) that will generate electric and magnetic fields (EMFs). EMFs are part of the natural world, and are also produced wherever electricity is generated, transmitted or used. Public exposure to power-frequency EMFs comes from a range of sources including household wiring and appliances, low-voltage distribution power lines or underground cables, and high-voltage transmission power lines or underground cables.

It is possible for strong power-frequency EMFs to have a detectible physiological effect on the body. Very extensive scientific research has been undertaken to investigate whether there is potential for adverse health effects from EMFs exposure. International and national health protection bodies have reviewed this data using a weight of evidence approach and have recommended conservative guidelines for public EMFs exposure, set to protect health.

Guidelines have been published by ICNIRP. They form the basis of an EC Recommendation and have been adopted in the UK, on the basis of advice from the government's scientific health advisors, in the form of a Code of Practice agreed with the electricity industry. This specifies reference levels that should not be exceeded in order to ensure public health protection.

The public health protection guideline reference level specified in the Code of Practice for magnetic field exposure is 360 μT (microteslas). For electric field exposure it is 9 $kV.m^{-1}$ (kilovolts per meter).

The Code of Practice states that compliance with the public exposure guidelines set to protect health may be assumed for all OHLs, underground cables and substations operated at 132 kV or less, without the need for more detailed assessment, on the basis of evidence published by the ENA showing that by design such infrastructure is not capable of causing exceedance of the public exposure guideline limits.

The ENA's statement of exposure guideline compliance is for large dual-circuit 132 kV OHLs. It states that the maximum magnetic field strength, calculated for 'worst case' conditions (i.e. with maximum load, minimum height clearance and untransposed phasing), is 40 μT, well below (11% of) the Code of Practice 360 μT public exposure guideline limit set to protect health. The maximum calculated electric field strength is 3.6 $kV.m^{-1}$, well below (40% of) the Code of Practice 9 $kV.m^{-1}$ public exposure guideline limit set to protect health. Electric and magnetic field strength from lower-voltage OHLs and UGCs associated with the proposed transmission infrastructure would be lower than these maxima.

The Proposed Development is for a smaller single-circuit OHL, operating at 33 kV. Further evidence of electric and magnetic field strengths published by the ENA for smaller 33 kV power lines indicates that typical field strengths would be significantly lower: a maximum of 0.9 $kV.m^{-1}$ and 25.7 μT underneath the OHL, with field strength further decreasing rapidly with distance away from the OHL. This is therefore compliant with the 1998 ICNIRP guidelines, as required by the SPPS for Northern Ireland.

Concerning the associated 33 kV underground cable connections, the cable sheath and fill material above the cables shields the electric field, with no measurable electric field strength expected above ground level. Magnetic field strengths from 33 kV underground cables are stated in the Code of Practice to be among the types of equipment that by design are not capable of exceeding the public exposure guidelines. Furthermore, an assessment undertaken using the specific UGC design specifications shows that the maximum magnetic field produced by the cable would be 1.82 μT, which would occur at ground level directly above the centreline. This is well below (0.5% of) the Code of Practice 360 μT public exposure guideline limit set to protect health and therefore also compliant with the 1998 ICNIRP guidelines, as required by the SPPS for Northern Ireland.

In conclusion, on the basis of the guidance for EMFs from electricity infrastructure adopted in the UK and the published evidence to support that, it is considered that the levels of power-frequency EMFs from the OHLs and UGCs of the proposed transmission infrastructure would be well below the guideline public exposure reference levels set to protect health. As such, the magnitude of impact would be negligible, with no identifiable health effects even taking a precautionary approach of assuming uniformly high sensitivity across the entire population.

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