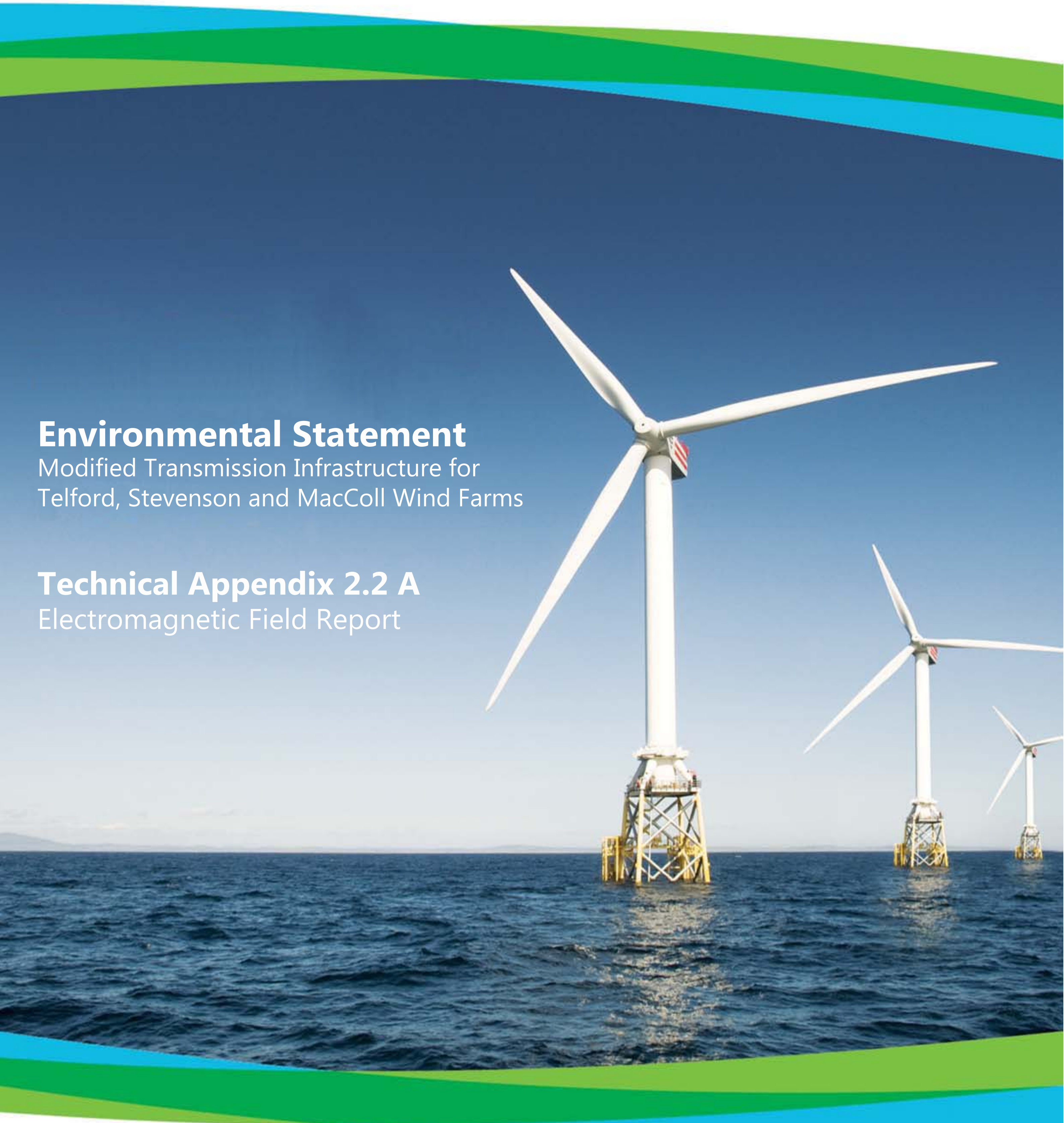
moray offshore renewables ltd

Developing Wind Energy In The Outer Moray Firth



Environmental Statement

Modified Transmission Infrastructure for Telford, Stevenson and MacColl Wind Farms

Technical Appendix 2.2 A

Electromagnetic Field Report

edp renewables

This document was produced by RPS Planning and Development on behalf of Moray Offshore Renewables Ltd

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Abbreviations and Acronyms

µT	Microtesla
CoP	Code of Practice
DECC	Department of Energy and Climate Change
EC	European Commission
ELF	Extremely low frequency
EMFs	Electric and magnetic fields
EU	European Union
HPA	Health Protection Agency (former)
HVAC	High voltage alternating current
Hz	Hertz
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation
kV	Kilovolts
mA	Milliamps
mm	Millimeters
NRPB	National Radiological Protection Board (former)
OnTI	Onshore transmission infrastructure
PHE	Public Health England
RMS	Root mean squared
SAGE	Stakeholder Advisory Group on ELF EMFs
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
WHO	World Health Organisation

1 Introduction

1. The modified onshore transmission infrastructure (OnTI) for the Telford, Stevenson and MacColl offshore wind farms will comprise onshore underground electricity cables running from the landfall point near Banff to two new onshore substations that provide a connection to the existing electricity grid southwest of New Deer. The underground cables and substations 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.

2. 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. High-voltage electricity transmission infrastructure can continuously generate comparatively strong ELF EMFs in close proximity to the infrastructure, and for this reason, an assessment has been undertaken of the maximum ELF EMFs strengths that would be generated by the modified OnTI, to show compliance with guidelines for public exposure to EMFs.

2 Approach

3. This technical appendix 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 any public perception of risk. In the following sections, the technical appendix sets out:

- Section 3 – an introduction to EMFs;
- Section 4 – a summary of the health evidence base and view of health protection bodies;
- Section 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 6 – a conservative assessment of the maximum ELF EMFs that could be produced by the modified OnTI, showing compliance with the guideline exposure standards; and
- Section 7 – a conclusion, bringing together the assessment's findings.

3 Electric and Magnetic Fields

4. 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.

5. ELF EMFs are part of the electromagnetic spectrum, which also encompasses radio waves, visible light, 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.

6. Unlike ionizing radiation found in the upper part of the electromagnetic spectrum (such as gamma rays given off 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'.

7. 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. As a general rule, the strength of radiated energy measured at a given point is inversely proportional to the square of distance from its source. EMFs strengths and electrical currents throughout this document are given as root mean square figures (RMS, an averaging calculation), due to the sinusoidal nature of current, voltage and EMFs in the context of HVAC transmission, which is the conventional scientific way of expressing these quantities.

Electric fields

8. 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.

9. 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 transmitted at higher voltages, from 11 kV up to 400 kV.

10. 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.

Magnetic fields

11. 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 time-varying magnetic field from alternating current (AC) mains electricity is separate to the Earth's natural (static) magnetic field, which varies between about 30 µT (microteslas) at the equator and 60 µT in high latitudes, being approximately 50 µT in Scotland (British Geological Survey, n.d.).

12. 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.

13. Typical residential exposure to ELF magnetic fields is in the range of 0.01 µT to 0.2 µT (Energy Networks Association, 2013). Low-voltage distribution circuits, household wiring and electrical appliances are typically the main source of residential exposure, although in some cases nearby high-voltage transmission can contribute to higher-than-average residential exposure (Maslanyj, et al., 2005). Electrical appliances can sometimes generate significant ELF magnetic fields (shown in Table 3.1), albeit in close proximity and with exposure therefore typically of a short duration.

Table 3.1: 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, n.d.) (citing German Federal Office for Radiation Safety)

4 Health Evidence Base

14. Electricity transmission and use are ubiquitous in the developed world, meaning that the entire population of a developed country such as Scotland 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 5.

15. 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.

16. 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 Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR); 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).

17. Possible health outcomes ranging from reproductive defects to cardiovascular and neurodegenerative diseases have been examined but have not been substantiated (McKinlay, et al., 2004) (McKinlay, et al., 2004) (ICNIRP, 1998) (ICNIRP, 2010) (Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), 2009) (SCENIHR, 2013).

Reproductive, cardiovascular, and neurodegenerative disease and genotoxic effects

18. 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 (WHO International Agency for Research on Cancer, 2002) that there is little evidence to support an association of exposure to ELF EMFs with adverse reproductive outcomes.

19. WHO, ICNIRP and SCENHIR report (WHO, 2007) (ICNIRP, 2010) (Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), 2009) 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.

20. A literature review article (Consales, et al., 2012) published in 2012 regarding ELF EMFs and neurodegenerative disorders provides 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.

21. The evidence regarding whether ELF EMF exposure is linked to, and a cause of, neurodegenerative disease is mixed. Epidemiological evidence correlates ELF EMF exposure with Alzheimer's and ALS disease incidence. However, the evidence does 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.

22. 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. Animal brain studies have shown convincing evidence of a neuroprotective effect in the case of Huntingdon's disease.

23. A 2009 study in Switzerland (Huss, et al., 2009) 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 (Frei, et al., 2013). SCENIHR's most recent (preliminary) opinion is that the evidence since 2009 does not support a conclusion that ELF EMFs exposure increases Alzheimer's disease risk (SCENIHR, 2013).

24. 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 (WHO International Agency for Research on Cancer, 2002) (WHO, 2007). 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.*" (Scientific Committee on Emerging and Newly Identified Health Risks, 2007), page 36, and in its 2009 opinion does not find any evidence sufficient to change that conclusion, stating that an association between cardiovascular disease and ELF EMF is "*considered unlikely*" (Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), 2009), page 43. This conclusion is supported by further heart disease studies from McNamee *et al* (McNamee, et al., 2010) (McNamee, et al., 2011).

25. ELF EMF is part of the non-ionising spectrum and as such does not have enough energy to cause direct cell damage to 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 (WHO, 2007).

Cancer

26. 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 (WHO International Agency for Research on Cancer, 2002) (WHO, 2007) (Kheifets, et al., 2010) (Sorahan, 2012).

27. A further common concern is the 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 (Health Protection Agency, 2006) 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 (WHO, 2007).

28. However, 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 271 other agents, including coffee, which may increase the risk of bladder cancer, while at the same time be protective against bowel cancer.

29. This classification is 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 conclude that the results of pooled analyses (Ahlbom, et al., 2000) (Greenland, et al., 2000) for a number of international studies reduce the possibility that this correlation is due to chance, but do not rule out potential bias or confounding variables. The evidence base for a **causal** link between ELF EMF and childhood leukaemia remains inconclusive, as despite extensive research, no plausible mechanism for a weak magnetic field to cause the disease has been established.

30. 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 EMF 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 EMF as a possible carcinogen (e.g. (Kheifets, 2010) (Schüz, 2011) (Sermage-Faure, et al., 2013) (Zhao, et al., 2014)), 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 in the near future, 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.

31. 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 (Draper, et al., 2005) 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 (Kroll, et al., 2010) 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 (Bunch, et al., 2014) 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. A study in Denmark (Pedersen, et al., 2014) designed using a comparable approach, 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 (Kheifets, et al., 2013) to further extend this evidence is underway in California.

32. This illustrates the difficulties of reliance on epidemiological evidence for a very small disease risk, and the need to consider the overall weight of evidence including animal and human cell studies.

33. 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 (Repacholi, 2012).

34. In the case of EMF and childhood leukaemia, the statistical evidence of epidemiological studies is mixed; and although taken together does suggest a risk, 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; and the existence of such a mechanism is considered biologically implausible.

35. As some evidence suggests 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. A paper published by Maslanyj *et al*, (Maslanyj, et al., 2010) 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*).

36. 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*” ((WHO, 2007), page 13) in view of uncertainties about the effects of chronic magnetic field exposure, but that due to the weakness of the evidence of 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*” ((ICNIRP, 2010), page 2).

37. The process that has been followed at a national level, to review the health evidence base and international guidance, consider with public and expert stakeholders whether additional precautionary measures are warranted, and set public health protection guidelines into policy, is summarised in the following section (5).

5 Public Exposure Guidelines

38. Health protection guidelines for public and occupational exposure to ELF EMFs have been published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 1998 (ICNIRP, 1998) and 2010 (ICNIRP, 2010). These guidelines have been reviewed and used in a number of sources of recommendations and advice on exposure to EMFs, including EC Recommendation 1999/519/EC (European Council, 1999) for the adoption of ICNIRP’s 1998 guidelines by member states of the EU.

39. 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 Public Health England (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 (McKinlay, et al., 2004) (McKinlay, et al., 2004).

40. 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 (Stakeholder Advisory Group on ELF EMFs (SAGE), 2007) 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.

41. The UK Government's response, published in 2009 (Department of Health; Department for Communities and Local Government; Department of Energy and Climate Change, 2009), 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.

42. Building on the outcomes of the SAGE process, in 2011 the Department of Energy and Climate Change (DECC) published a voluntary code of practice (CoP) detailing the recommended approach for demonstrating compliance with adopted ELF EMFs exposure guidelines, subsequently updated in March 2012 (DECC, 2012). 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 ICNIRP guidance for AC fields under the terms of the 1999 EC Recommendation, in the UK context.

43. Use of the CoP to show compliance with guideline public exposure limits set out within it for Nationally Significant Infrastructure Projects (NSIPs) forms part of the National Policy Statement for Electricity Networks Infrastructure (NPS EN-5), in section 2.10. Although this planning policy is applicable to England and Wales, not Scotland, the position of the Scottish Executive and Parliament regarding ELF EMFs from electricity transmission infrastructure has been to follow the advice of the UK HPA (now PHE): see (Public Petitions Committee, 2011) and the history of public petition PE00812, available at (Public Petitions Committee, n.d.). It is therefore considered that the CoP is the most appropriate guidance to follow in the context of the OnTI for this Project.

44. 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 technical appendix. The CoP

specifies on page five that compliance of infrastructure at voltages of >132 kV (the onshore underground cables will be at 220 kV) should be shown by "*a calculation or measurement of the maximum fields (i.e. directly under the line, or directly above the cable)*". It goes on to state on page six that calculations will usually be the preferred method of demonstrating compliance for underground cables. On pages five and six, the CoP details the operating conditions under which compliance should be assessed and the acceptable methods of calculation.

45. 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*" ((DECC, 2012), page 4).

46. Public exposure to ELF EMFs from the OnTI will be both transient (e.g. on public footpaths) and residential, as there are a number of properties and small settlements within the cable route corridor. To be conservative, ELF EMFs exposure from the OnTI have been assessed against the public exposure guideline in this technical appendix.

47. Table 5.1 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.

Table 5.1: 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, 1998) (DECC, 2012)

48. Although ICNIRP published updated guidance in 2010 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.

49. The reference levels given in the CoP are those specified by the former HPA, on the basis of modelling undertaken by Dimbylow (Dimbylow, 2005). This assessment is undertaken against the public exposure guideline reference level values given in the CoP, of 9 $kV.m^{-1}$ for electric fields and 360 µT for magnetic fields.

6 Electric and Magnetic Fields from the Underground Cables and Substation

Measures adopted as part of the project

50. Underground power cables, as opposed to the alternative of overhead power lines for onshore HVAC transmission, do not produce an external electric field at ground level. In addition, the closer spacing of the cable carrying each power phase in underground cable designs can lead to a more rapid decrease in magnetic field strength with distance from the cable, relative to the equivalent typical overhead power line design.

Modified OnTI parameters and route

51. The modified OnTI will comprise up to four 220 kV onshore underground cables and two onshore substations. The modified OnTI area, with cable route corridor and works area for the onshore substations, is shown in Figure 6.1.

52. The underground cables will be buried at a minimum of 0.8 m depth, typically in 1 m depth backfilled trenches, although in some sections deeper horizontal directional drilling (HDD) may be used to cross under obstacles such as roads or watercourses. Each circuit comprises three conductors, carrying the three phases of HVAC power. There will be up to four 220 kV circuits (12 conductors). The maximum current of the 220 kV cables will be 630 A.

53. The three conductors of each circuit can either be laid bundled together in a trefoil formation (see Figure 6.2) or laid flat alongside each other (see Figure 6.3). The trefoil design typically leads to a lower maximum magnetic field strength and this will be the primary layout used along the cable route. A flat formation may be used in short sections at cable jointing bays, where two sections of cable are joined. Both designs have been assessed.

54. Either two or four trenches may be used for the four circuits. If two trenches are used, with two circuits per trench, the circuit spacing will be 3 m (as shown for two of the four circuits in Figure 6.3 and Figure 6.3) and spacing between the trenches will be 4 m. If four trenches are used, one for each circuit, the spacing between all circuits will be 4 m.

Figure 6.1: Onshore underground cable route corridor and substation works area

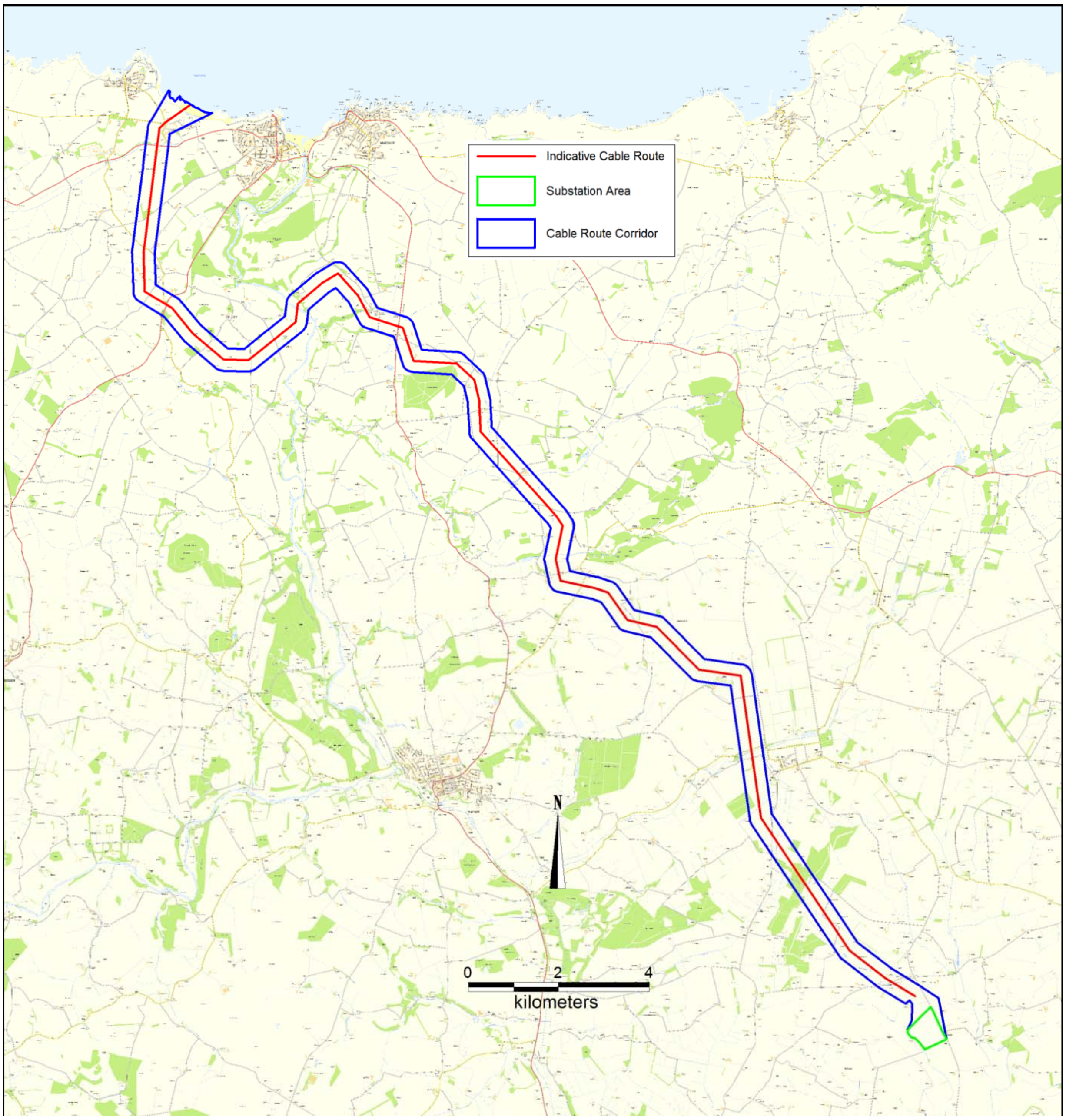
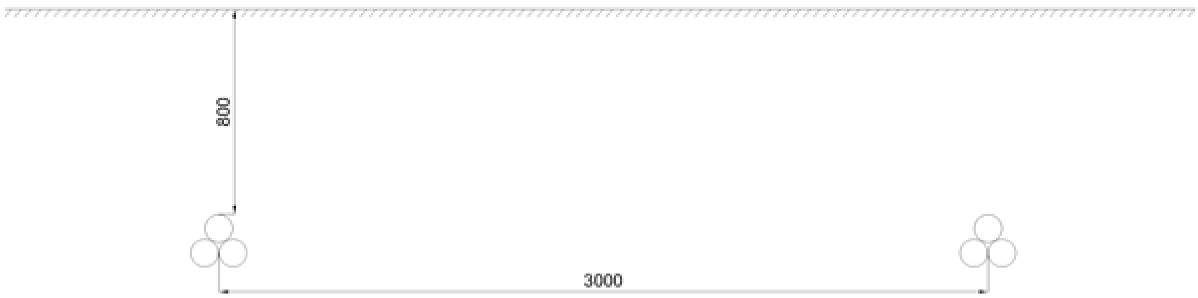
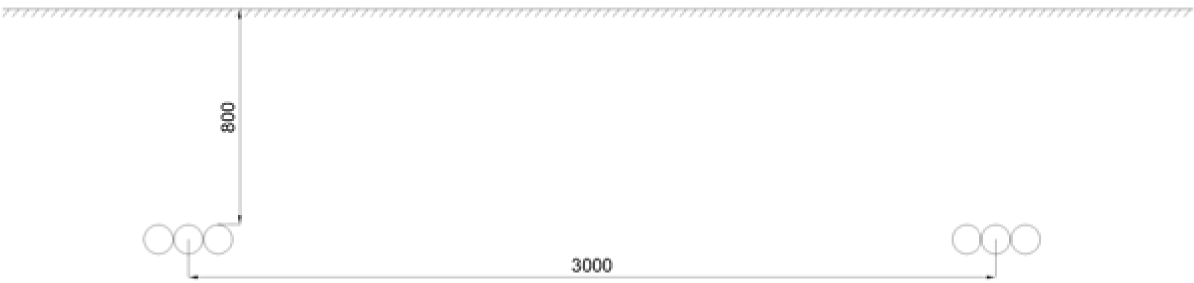


Figure 6.2: Two HVAC circuits with trefoil layout



Dimensions in mm

Figure 6.3: Two HVAC circuits with flat layout



Dimensions in mm

55. Due to the vector nature of magnetic fields and the fact that field strength decreases rapidly with distance from source, the magnetic field at a given location is typically dominated by the closest source, even when multiple similar sources are present. This assessment therefore provided calculation of the magnetic field strength only from the underground cables and the interaction of fields between the four circuits.

56. Table 6.1 summarises the underground cable design parameters that have been assessed.

Table 6.1: Underground cable design parameters

Parameter	Value	
Circuits	4	
Conductors	12	
Spacing between conductors	Nil	
Spacing between circuits (from central conductor)	3 m within trench	4 m between trenches
Minimum burial depth (to top of conductors as worst case scenario)	0.8 m	
Maximum current	630 A	

EMFs from the underground cables

57. Magnetic field strength generated by the underground cables has been calculated following the approach set out in the CoP. Results are set out in Table 6.2 and Table 6.3. Distances are from the centreline of the four 220 kV circuits and results are at 1 m above ground level.

Table 6.2: Maximum magnetic field strength from 220 kV underground cables

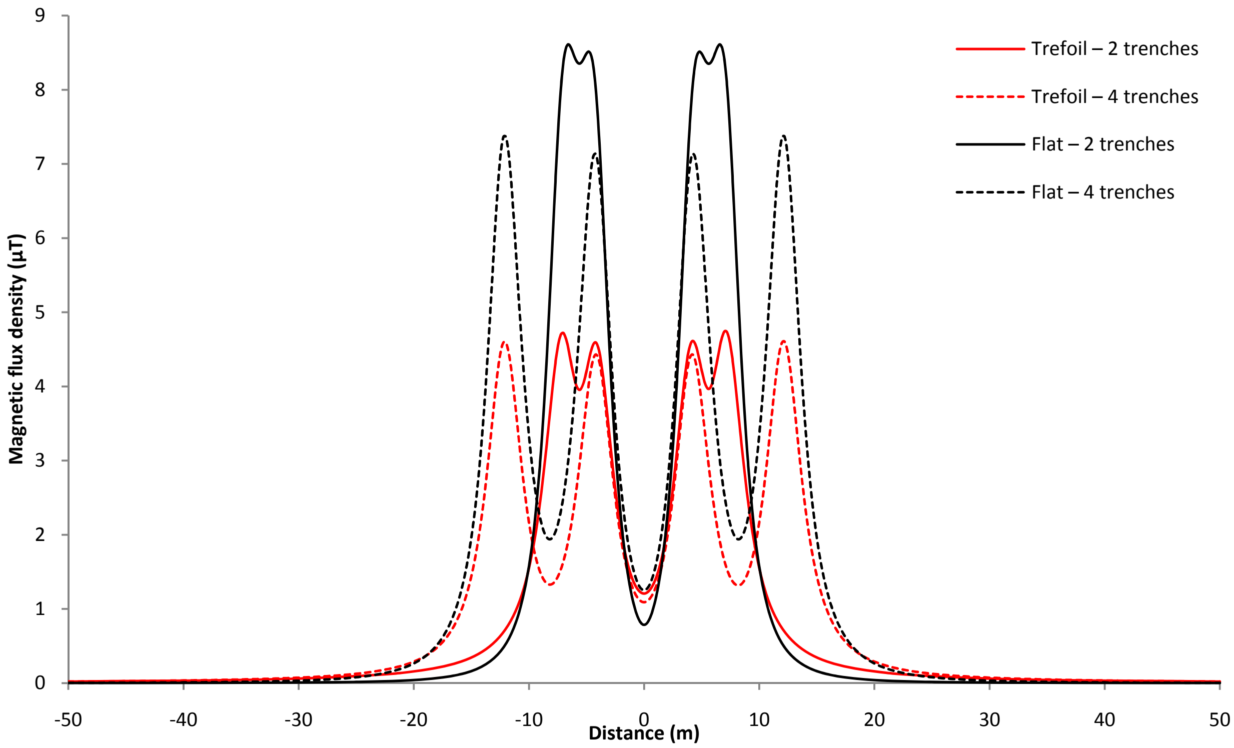
Guideline public exposure limit	360 µT		
Scenario	**Magnetic field strength (µT)**	**Proportion of guideline exposure limit**	**Distance**
Trefoil – two trenches	4.74 µT	1.32 %	7.0 m
Trefoil – four trenches	4.60 µT	1.28 %	12.2 m
Flat – two trenches	8.61 µT	2.39 %	6.6 m
Flat – four trenches	7.37 µT	2.05 %	12.2 m

Table 6.3: Magnetic field strength by distance from 220 kV underground cables

Guideline public exposure limit	360 µT			
Distance (m)	Magnetic field strength (µT)			
	Trefoil – two trenches	Trefoil – four trenches	Flat – two trenches	Flat – four trenches
0	1.21	1.09	0.79	1.25
5	4.22	3.78	8.49	6.20
10	1.55	2.16	1.57	3.34
15	0.35	1.45	0.16	1.96
20	0.16	0.29	0.04	0.26
25	0.09	0.13	0.02	0.08
30	0.06	0.07	0.01	0.03

58. The maximum magnetic field strength from the underground cables, in either flat or trefoil formation, will be well below the guideline public exposure limit set to protect health. The maximum magnetic field strength calculated is 8.6 µT, 2.4 % of the 360 µT public exposure guideline limit. The maximum field strength occurs above the outer conductors; distance from the source and cancellation in the magnetic fields leads to a lower field strength in the centreline between the circuits. Trefoil formation leads to a lower peak magnetic field strength, but as noted the maximum flat formation field strength is well within the guideline public exposure limit set to protect health. The magnetic field strength decreases rapidly with distance from the cables, as illustrated in Figure 6.4.

Figure 6.4: Magnetic field strength from 220 kV underground cables



EMFs from the onshore substations

59. The onshore substations will also be a source of both electric and magnetic fields. Due to the distance between substation components and the closest publically-accessible point (the perimeter fence), the greatest EMFs exposure in the vicinity of substations is typically from the overhead lines or underground cables entering and exiting them. The magnetic field strength from the underground cables, connecting with the onshore substations, has been assessed in the section above.

60. The onshore substation building walls or perimeter fence will provide screening of the electric field, and the existing 275 kV overhead line (part of the national grid) would be the greatest source of electric field exposure in the area. Compliance of overhead line designs with the guideline public exposure limit set to protect health is established by National Grid.

Occupational EMFs exposure

61. The OnTI will be designed and operated in accordance with all relevant health and safety legislation. The Offshore Transmission Owner (OFTO) will undertake appropriate occupational exposure assessments, as necessary, to ensure the safety of maintenance workers for the OnTI once they are operational and generating EMFs. MORL and the OFTO will have regard to the guidance of the Health and Safety Executive, to the occupational exposure guidelines published by ICNIRP, and to the general duty of care to employees under the Health and Safety Act (1974) and relevant health and safety regulations. No national legislation specific to occupational EMFs health and safety presently exists. However, EU

Directive 2013/35/EU (European Parliament and Council, 2013) sets requirements for assessment of occupational exposure, consistent with ICNIRP guidelines, which will be transposed into national legislation by 2016. This provides for compliance with occupational EMFs exposure standards set to protect workers' health.

7 Conclusion

62. The onshore transmission infrastructure (OnTI) will comprise up to four 220 kV export cable circuits and two onshore substations, that 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 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.

63. Strong EMFs are known 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. These guidelines have been adopted in the UK and are applied using a Code of Practice for electricity transmission infrastructure.

64. Electric fields generated by the onshore underground cables will be fully screened by the cable sheath and their burial in the ground. No electric field will be experienced above ground level. The onshore substation building walls or perimeter fence will also offer screening of the electric field, and the field strength from it will not be significant relative to the existing nearby 275 kV overhead line.

65. The maximum magnetic field that would be generated by the underground export cables, using worst-case assumptions regarding design parameters, has been calculated in line with the Code of Practice approach. The calculation results show that this maximum magnetic field strength would be 8.6 μT, 2.4 % of the 360 μT guideline public exposure limit set to protect health.

66. Due to the distance between substation components and the closest publically-accessible point (the outer wall or perimeter fence), the greatest EMFs exposure in the vicinity of substations is typically from the overhead lines or underground cables entering and exiting them. The magnetic field strength from the underground export cables connecting with the onshore substation has been assessed and forms a conservative proxy for magnetic field exposure from the onshore substation. The onshore substation will be designed and operated in accordance with all relevant health and safety legislation and the occupational exposure guidelines for EMF, to protect the health of workers and maintenance staff accessing the OnTI.

67. In conclusion, a conservative assessment has shown that EMFs from the OnTI will be well below the adopted guideline public exposure limits set to protect health and no measurable adverse health impacts as a result of public exposure to EMFs from the OnTI are anticipated.

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