Rampion 2 WIND FARM

Rampion 2 Wind Farm

Category 6: Environmental Statement

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Executive Summary

This electric and magnetic fields (EMF) health evidence base has been undertaken to support the assessment in **Chapter 28: Population and human health, Volume 2** of the ES (Document Reference: 6.2.28) of the static and extremely low frequency (ELF) EMFs that would be generated by the Rampion 2 onshore transmission infrastructure. This appendix provides a summary of the health evidence base and guideline exposure standards set to be protective of human health.

Extensive scientific research has been undertaken, particularly over the last 40 years, into the potential for static or ELF EMFs exposure to cause adverse health effects. Possible health outcomes ranging from reproductive defects to cardiovascular and neurodegenerative diseases have been examined but have not been substantiated. Similarly, potential for ELF EMFs to cause cancer has been extensively studied. However, no causal link with cancers, such as adult leukaemia, brain tumours and breast cancer, has been established.

Despite a lack of evidence to conclusively report adverse health effects caused by ELF EMFs, a precautionary approach to EMF is considered to be both reasonable and warranted in view of uncertainties about the effects of chronic magnetic field exposure. It is this precautionary approach that the International Commission on Non-Ionizing Radiation Protection (ICNIRP) have adopted when publishing the health protection guidelines for public and occupational exposure to static and ELF EMFs. The 1998 ICNIRP guidelines, as adopted in the UK under the 1999 European Commission Recommendation, have been used in this project for the AC (time-varying) fields and the 1994 ICNIRP guidelines, as adopted in the UK under the 1999 European Commission Recommendation, have been used for the DC (static) magnetic fields. As a conservative measure, EMFs exposure from the Rampion 2 onshore transmission infrastructure has been assessed against the general public (as opposed to occupational) exposure guidelines.

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1. EMF and Health

1.1 Introduction

1.1.1 This onshore electricity transmission infrastructure for Rampion 2 will comprise buried cables that will run in a single corridor (approximately 38.8km) from the landfall at Climping through to the new onshore substation at Oakendene.

1.1.2 The up to 275kV cable system along the onshore cable route will comprise between two and four cable circuits in separate trenches with two circuits operating at 275kV representing the worst-case scenario. Each circuit will contain three Power Cables (HVACs) and two Fibre Optic Cables (FOCs) drawn through pre-installed ducts.

1.1.3 The 400 kV cable system between the new onshore Oakendene substation at Oakendene and the existing National Grid Bolney substation will comprise two cable circuits in separate trenches. Each circuit will contain three Power Cables and two FOCs drawn through pre-installed ducts.

1.1.4 Full details of the onshore transmission infrastructure and its design envelope are provided in **Chapter 4: The Proposed Development, Volume 2** of the ES (Document Reference: 6.2.4).

1.1.5 The onshore transmission infrastructure will generate electric and magnetic fields (EMFs) when in operation. HVAC infrastructure will generate EMFs principally at 50 Hz and High Voltage Direct Current (HVDC) infrastructure will generate static fields (0 Hz). The 50 Hz 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. Static EMFs are also common, generated by some electrified rail systems for example. 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.

1.1.6 This appendix provides a summary of the health evidence base and guideline exposure standards set to protect health to support the assessment in **Chapter 28: Population and human health, Volume 2** of the ES (Document Reference: 6.2.28) of the static and ELF EMFs that would be generated by the Rampion 2 onshore transmission infrastructure, giving maximum predicted field strengths to assess compliance with health protection guidelines for public exposure to EMFs.

1.1.7 This appendix is not concerned with EMFs generated by offshore transmission infrastructure or any assessment of potential impacts to offshore ecology, which is considered in **Chapter 22: Terrestrial ecology and nature conservation, Volume 2** of the ES (Document Reference: 6.2.22). It is not concerned with occupational exposure to EMFs (e.g. for maintenance workers once the onshore transmission infrastructure is operational). The operator will be subject to the Control of Electromagnetic Fields at Work Regulations 2016 (SI 2016 No. 588 Health and Safety) and to the general duty of care to employees under the Health and Safety at Work Act (1974) and relevant health and safety regulations. It is also

expected that the operator will have regard to the guidance from the Health and Safety Executive (HSE) and to the occupational exposure guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Consultation

1.1.8 An Environmental Impact Assessment (EIA) Scoping Report was submitted to the Planning Inspectorate in July 2020, and the Secretary of State has provided a Scoping Opinion dated August 2020 that appends the responses of statutory consultees including local authorities and the former Public Health England (PHE), now integrated within the Office for Health Improvements and Disparities (OHID).

1.1.9 PHE's consultation response refers to its standing advice on the health effects of ELF EMFs, to public health protection exposure guidelines and the UK government's policy in that regard, and to the former Department of Energy and Climate Change's (DECC) voluntary Code of Practice (DECC, 2012a) that is followed by the electricity industry. These sources of health protection advice and guidelines are discussed in detail in **Section 1.3** of this Appendix.

1.1.10 West Sussex County Council (WSCC) is the only other section 49 statutory consultee who have raised matters concerning EMFs and public health in the Scoping Opinion, whereby they state that WSCC would expect to see any EMF effects covered by the assessment work undertaken.

Approach and Structure

1.1.11 The approach to this assessment seeks to provide information regarding 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 appendix structure is as follows:

- remainder of this section – an introduction to EMFs;
- **Section 1.2** – a summary of the health evidence base and view of health protection bodies; and
- **Section 1.3** – the guideline exposure standards set to protect health, with discussion of how these have been adopted in the UK and how they are applied.

Electric and Magnetic Fields

1.1.12 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.

1.1.13 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 or for static fields, it is appropriate to think in terms of separate electric and magnetic fields.

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

1.1.15 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 from a given line source is inversely proportional to the square of distance from its source. ELF 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

1.1.16 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. Electric field strengths are typically expressed in kilovolts per metre ($kV.m^{-1}$).

1.1.17 The static atmospheric electric field at ground level is normally about 100volts 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 230V but outside homes it is distributed and transmitted at higher voltages, from 400V up to 400kV in the UK.

1.1.18 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 the grounding of the cable sheath.

Magnetic Fields

1.1.19 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. Magnetic field strengths are expressed in microteslas (μT).

1.1.20 The strength of both static and time-varying magnetic fields 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.

1.1.21 Typical residential exposure to ELF magnetic fields is in the range of 0.01μT (microteslas) to 0.2μT (Energy Networks Association, 2013). 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 (Maslanyj, et al., 2005). Electrical appliances can sometimes generate significant ELF magnetic fields (shown in **Table 1-1**), albeit in close proximity and with exposure therefore typically of a short duration.

1.1.22 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 30μT at the equator and 60 μT in high latitudes, being approximately 50μT in the UK (British Geological Survey, n.d.).

1.1.23 Magnetic field strength B (strictly speaking magnetic flux density) can be calculated using the Biot-Savart law, from which the following equation can be derived:

$$B = \frac{\mu_0 I}{2 \pi r}$$

1.1.24 Where:

B = Magnetic flux density (T)

μ_0 = Permeability of free space = 4 x π x 10^{-7} (H m^{-1})

I = Current through conductor (A)

r = Distance from centre of conductor (m)

Table 1-1: 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

Source: (WHO, 2016) (citing German Federal Office for Radiation Safety)

1.2 Health Evidence Base

1.2.1 Electricity transmission and use is ubiquitous in the developed world, meaning that the entire population of a developed country such as the UK experiences ELF EMFs exposure in daily life. Strong static and 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 static or ELF EMFs exposure to cause adverse health

effects. This research has formed the basis for health protection guidelines discussed in **Section 1.3**.

HVAC ELF EMFs

1.2.2 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 two decades, to summarise the findings of published research, form conclusions and give health protection advice (where applicable) based on the weight of evidence.

1.2.3 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 Protection (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 PHE.

1.2.4 Possible health outcomes ranging from reproductive defects to cardiovascular and neurodegenerative diseases have been examined but have not been substantiated (ICNIRP, 1998; ICNIRP, 2010; McKinlay, et al., 2004; McKinlay, et al., 2004; SCENIHR, 2009; SCENIHR, 2013; SCENIHR, 2015).

Reproductive, Cardiovascular, Neurodegenerative Disease and Genotoxic Effects

1.2.5 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 (2002) concluded in 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 (SCENIHR, 2015).

1.2.6 WHO (2007), ICNIRP (2010) and (SCENIHR, 2009) have reported 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.

1.2.7 A literature review article (Consales, et al., 2012) 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.

1.2.8 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.

1.2.9 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.

1.2.10 A 2009 study in Switzerland (Huss, et al., 2009) found an association between close residential proximity (<50m) 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). A recent occupational exposure study of ALS found an association with ELF magnetic field exposure, identified by proxy using job categories (Koeman, et al., 2017) and a similar cohort study of Danish utility workers, again using job categories to estimate exposure found mixed evidence: higher risks of dementia, motor neurone disease, multiple sclerosis and epilepsy in the highest exposure category but a lower risk (than the general population average) for Parkinson's disease (Pedersen, et al., 2017). 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 (Sorahan & Mohammed, 2014). 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 (SCENIHR, 2015).

1.2.11 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 (IARC, 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."* (SCENIHR, 2007) (page 36) and in its 2009 opinion did not find any evidence sufficient to change that conclusion, stating that an association between cardiovascular disease and ELF EMFs is *"considered unlikely"* (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).

1.2.12 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 (WHO, 2007).

Cancer

1.2.13 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 (IARC, 2002; Kheifets, et al., 2010; Sorahan, 2012; WHO, 2007).

1.2.14 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).

1.2.15 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 299 other agents, including Aloe vera[1].

1.2.16 This classification is based on evidence that a correlation has been found between chronic exposure to weak ELF magnetic fields (at around 0.3–0.4microtesla 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 EMFs and childhood leukaemia remains inconclusive, as despite extensive research, no plausible mechanism for a weak magnetic field to cause the disease has been established.

[1] Aloe vera has 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.

1.2.17 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 0.3–0.4μT, continues to support the IARC classification of ELF EMFs 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 shown. 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.

1.2.18 The 'Advanced Research on Interaction Mechanisms of electroMagnetic exposures with Organisms for Risk Assessment' (ARIMMORA) project has further assessed *"the underlying biophysical mechanisms and to clarify a possible causal relationship between ELF MF exposure and cancer, especially childhood leukaemia"* (ARIMMORA Partners, n.d.) (page 2) and has undertaken a risk assessment following the IARC methodology. A mouse model of the most common form of childhood leukaemia developed for the project allowed further investigation of possible causal mechanisms, but further research was called for before definitive conclusions could be drawn (Schüz, et al., 2016). The risk assessment concluded that the evidence reviewed was still consistent with the IARC group 2B classification and was "insufficient to impact decisions on safety policy at present" (ARIMMORA Partners, n.d.) (page 19). The final report called for research to be accelerated and a precautionary approach for ELF magnetic field exposure to continue to be applied (ibid).

1.2.19 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.

1.2.20 The study was extended again in 2014 (Bunch, et al., 2014) to add evidence from Scotland and for 132kV 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 200m or 600m of high-voltage power lines. A third comparable study (Kheifets, et al., 2015) to further extend this evidence has been undertaken in California, and found a slight excess of childhood leukaemia cases

within 50m of a transmission line over 200kV (albeit with a wide confidence interval), but no evidence of increased risk at distances beyond 50m, for lower-voltage lines, or for cancers of the central nervous system (Crespi, et al., 2016).

1.2.21 Overall 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.

1.2.22 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) (Bradford Hill, 1965; Repacholi, 2012).

1.2.23 In the case of EMFs and childhood leukaemia, the statistical evidence of epidemiological studies is mixed; and although taken together does 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; and the existence of such a mechanism is considered biologically implausible by the health protection bodies cited above.

1.2.24 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 >0.3–0.4μT, 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).

1.2.25 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 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. It is also consistent with the ARIMMORA risk assessment recommendations for

"prudent avoidance" between power lines and schools or nurseries (Bounds, 2015) (section 6).

1.2.26 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).

1.2.27 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 **Section 1.3**.

1.3 Public Exposure Guidelines

Development of Guidelines

1.3.1 Research in the ELF EMF range began more than 40 years ago, and there is now a large body of literature available on which ICNIRP set its protection guidelines (ICNIRP, 2020).

1.3.2 Health protection guidelines for public and occupational exposure to static and ELF EMFs have been published by ICNIRP in 1994, 1998, 2009 and 2010. These guidelines have been reviewed and used in a number of sources of recommendations and advice on exposure to EMFs, including European Commission (EC) Recommendation 1999/519/EC (European Council, 1999) for the adoption of ICNIRP's 1994 and 1998 guidelines by member states of the European Union (EU). A further EU Directive (2013/35/EU) (European Parliament and Council, 2013) relates specifically to the health and safety of workers in environments affected by EMFs and has been transposed into UK legislation as the *Control of Electromagnetic Fields at Work Regulations 2016 (SI 2016 No. 588 Health and Safety)*.

1.3.3 In the UK, the former Health Protection Agency's (HPA's) Radiation Protection Division[2] recommended that the UK adopts the 1998 ICNIRP guidelines, and the government responded by adopting the guidelines under the terms of the EC Recommendation. 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).

1.3.4 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

[2] The Radiation Protection Division was formed in 2005 from the former 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.

an inclusive process. In 2007, SAGE's first interim assessment (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.

1.3.5 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.

1.3.6 Building on the outcomes of the SAGE process, in 2011 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, 2012b). 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.

1.3.7 The CoP (DECC, 2012b) is used to show compliance with guideline public exposure limits for Nationally Significant Infrastructure Projects (NSIPs) in England and Wales.

1.3.8 ICNIRP iteratively review the available literature to acknowledge possible knowledge gaps that if addressed, would assist ICNIRP in further developing guidelines and setting revised recommendations on limiting exposure to electric and magnetic fields. This was most recently completed in 2020 (ICNIRP, 2020), whereby it was concluded that further research is not considered necessary in the following research areas for guideline development:

- neurobehaviour;
- inflammation and the immune system;
- endocrine system;
- reproduction and development;
- cardiovascular disorders;
- health effects from co-exposure with ELF-MF; and
- magnetite.

1.3.9 **Table 1-2** outlines the areas of research which have been identified as potentially relevant for setting guidelines due to data gaps.

Table 1-2: Data gaps in knowledge related to low frequency electric and magnetic fields and health

Topic	Robustness	Consistency	Comments
Pain perception	In general, limited, and heterogeneous human research showing no effect for most endpoints. Contact current literature is limited to one study.	Inconsistent results between human and animal data in general. Contact current literature on pain consists of only one single study.	Data gap only identified in relation to contact currents. Further studies on contact currents are therefore recommended.
Neurodegenerative disorders	Research in this area is not robust.	Inconsistent results.	Further epidemiological and experimental studies on Alzheimer's disease and ALS would be useful.
Childhood leukaemia	Limited research using adequate animal models is not robust. Substantial number of epidemiological studies of ELF-MF and childhood leukaemia.	Generally no support for cancer induction or promotion from animal models. Consistent results from epidemiological studies on childhood leukaemia indicate increased risk, but weaker findings over time.	Further studies on mechanisms and biological data from childhood leukaemia experimental models are recommended. No further epidemiological studies unless a biologically based hypothesis can be formulated.
Neural network firing patterns	Well established phenomena.	Wide range of estimates of sensitivities.	Uncertainties in precise mechanism and derivation of tissue E-fields implies that actual

Topic	Robustness	Consistency	Comments
			thresholds could be lower (or higher) than current levels.
Free radical lifetimes	Effect of magnetic fields on free radical lifetimes well-established, but at higher field values than reference levels.	The radical pair mechanism is the only physically plausible way in which biological systems may be sensitive to low intensity magnetic fields. Observations are far from sufficient to explain predict health effects and to require consideration in terms of guidelines.	Ongoing research outcomes may motivate revision of conclusions regarding relevance to standard-setting.
Dosimetry & modelling	A certain number of reports on MF exposure, but not robust in some cases. Limited research on ELF exposure, contact current and non-sinusoidal wave exposures.	Some inter-comparison between models, but more needed. More critical examination of assumptions made required.	Considerable gaps remain.

Source: (ICNIRP, 2020)

National Policy Statement EN-5

1.3.10 Guidance on the issues to be assessed for offshore renewable energy developments has been obtained through reference to the Overarching National Policy Statement (NPS) for Energy (EN-1) (DECC, 2011a), the NPS for Renewable Energy Infrastructure (EN-3) (DECC, 2011b) and the NPS for Electricity Networks Infrastructure (EN-5) (DECC, 2011c). NPS EN-1 and NPS EN-3 refer to NPS EN-5 as the primary guidance document in relation to onshore grid connection infrastructure.

1.3.11 NPS EN-5 (DECC, 2011c) Section 2.10 reviews the sources of advice, guidelines, and recommendations on EMF. At paragraph 2.10.5 it states that *"Government*

policy is that exposure of the public should comply with the ICNIRP (1998) guidelines in terms of the EU Recommendation. The electricity industry has agreed to follow this policy. Applications should show evidence of this compliance as specified in 2.10.9 below".

1.3.12 Paragraph 2.10.9 states that *"Government has developed with the electricity industry a Code of Practice…that specifies the evidence acceptable to show compliance with ICNIRP (1998) in terms of the EU Recommendation. Before granting consent to an overhead line application, the IPC [now PINS] should satisfy itself that the proposal is in accordance with the guidelines, considering the evidence provided by the applicant and any other relevant evidence."*

1.3.13 NPS EN-5 states at paragraph 2.10.15 that the applicant should have considered factors relevant to ensuring compliance with the Electricity Safety, Quality and Continuity Regulations 2002: optimal phasing of overhead lines, and any new advice emerging from the Department of Health. It goes on to state in this paragraph that *"…where it can be shown that the line will comply with the current public exposure guidelines and the policy on phasing, no further mitigation should be necessary."*

1.3.14 The draft NPS EN-5 (DESNZ, 2023) provides an update to the 2011 version. The document echoes the previous version, stating in paragraph 2.9.48 that to prevent known adverse health effects, *"the ICNIRP developed health protection guidelines in 1998 for both public and occupational exposure. These are expressed in terms of the induced current density in affected tissues of the body, 'basic restrictions', and in terms of measurable 'reference levels' of electric field strength (for electric fields), and magnetic flux density (for magnetic fields)."*

1.3.15 Paragraph 2.9.49 then goes on to explain that *"the reference levels are such that compliance with them will ensure that the basic restrictions are not reached or exceeded"* and in paragraph 2.9.57 that *"the levels of EMFs produced by power lines in normal operation are usually considerably lower than the ICNIRP 1998 reference levels"*.

1.3.16 Reference is made to SAGE and NIHP CRCE in paragraphs 2.9.52 and 2.9.53 to their roles in providing advice to government on limiting public exposure to EMF. Importantly, in paragraph 2.9.56, it states that *"the balance of scientific evidence over several decades of research has not proven a causal link between EMFs and cancer or any other disease. The NIHP CRCE keeps under review emerging scientific research and/or studies that may link EMF exposure with various health problems and provides advice to the Department of Health and Social Care on the possible need for introducing further precautionary measures"*.

1.3.17 Regarding mitigation, the draft NPS EN-5 states that *"where EMF exposure is within the relevant public exposure guidelines, re-routeing a proposed overhead line purely on the basis of EMF exposure or undergrounding a line solely to further reduce the level of EMF exposure are unlikely to be proportionate mitigation measures"*.

1.3.18 In terms of decision making, the draft NPS EN-5 refers to both the ICNIRP 1998 guidelines and DECC CoP in paragraph 2.11.8, and that the SoS should be satisfied that the proposal is in accordance with the guidelines.

1.3.19 There is no direct provision in the planning system relating to health protection from EMF (DECC, 2011a).

Code of Practice

1.3.20 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 annex. The CoP specifies on page five that compliance of overhead lines and underground cables at voltages of >132kV 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 ≤132kV, the CoP states that compliance with the public exposure guidelines is assumed, based on evidence published by the Energy Networks Association for types of infrastructure that by design are not capable of causing exceedance of the public exposure guideline limits.

1.3.21 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).

Guidelines Used in the Assessment

1.3.22 Public exposure to EMFs from the Rampion 2 onshore transmission infrastructure will be both transient (e.g. on public footpaths) and residential. To be conservative, EMFs exposure from the Rampion 2 onshore transmission infrastructure has therefore been assessed against the general public (as opposed to occupational) exposure guideline.

1.3.23 **Table 1-3** summarises the relevant AC (time-varying) and DC (static) field exposure guidelines. For AC fields, 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 (Dimbylow, n.d.). For DC fields, although the ICNIRP guideline level for magnetic field exposure is 40mT (1994) or 400mT (2009), ICNIRP discusses the need for *"practical policies… to prevent inadvertent harmful exposure of people with implanted electronic medical devices and implants containing ferromagnetic materials, and injuries due to flying ferromagnetic objects"* (ICNIRP, 2009) (page 511) and in that context makes reference to a lower restriction level of 0.5mT

suggested by the International Electrotechnical Commission (IEC) in 2002 (International Electrotechnical Commission, 2002).

Table 1-3: Static and ELF EMFs exposure guidelines adopted in the UK

Description		Occupational	Public
AC fields – 1998 ICNIRP guidelines, as adopted in the UK under the 1999 EC Recommendation and in the CoP			
'Basic restriction' (the quantity that must not be exceeded)	Induced current density in the central nervous system	10mA m-2	2mA m-2
ICNIRP reference level (not a limit in itself but a guideline for when 'basic restriction' investigation may be required)	Magnetic field	500μT	100μT
	Electric field	10kV m-1	5kV m-1
CoP reference level (not a limit in itself but a guideline for when 'basic restriction' investigation may be required)	Magnetic field	1,800μT	360μT
	Electric field	46kV m-1	9 kVm-1
DC magnetic fields – 1994 ICNIRP guidelines, as adopted in the UK under the 1999 EC Recommendation			
'Basic restriction' (the quantity that must not be exceeded)	Magnetic field. 'Ceiling value' (occupational) and continuous exposure (public)	2T	40mT
ICNIRP / IEC indirect effects protective value	Magnetic field. Indirect effects (movement of ferromagnetic objects and implants, including pacemakers)	n/a	0.5mT

Sources: (ICNIRP, 1994; ICNIRP, 1998; European Council, 1999; DECC, 2012b)

1.3.24 Although ICNIRP published updated guidance for 50Hz magnetic fields in 2010 (ICNIRP, 2010) that gives a less stringent 200μT reference level for general public magnetic field exposure, due to changes in the basis of the basic restriction, and updated guidance giving a less stringent 400mT level for static magnetic fields (ICNIRP, 2009), the 1999 EC recommendation for use of the more stringent 1998

and 1994 ICNIRP guidance, respectively, remains the basis of UK guidance and the CoP.

1.3.25 A second Code of Practice (DECC, 2012a), likewise arising from the SAGE recommendations, 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. However, this Code of Practice is applicable specifically for dual-circuit overhead power lines and is not applicable to the proposed development, where underground cables are closely grouped together in a trench and may be bundled in a trefoil formation.

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2. Glossary of terms and abbreviations

Term (acronym)	Definition
AC	Alternating Current
ALS	Amyotrophic Lateral Sclerosis
ARIMMORA	Advanced Research on Interaction Mechanisms of electroMagnetic exposures with Organisms for Risk Assessment
CoP	Code of Practice
DC	Direct current
DECC	Department of Energy and Climate Change
EC	European Commission
EIA	Environmental Impact Assessment
ELF	extremely low frequency
EMF	electric and magnetic fields
EU	European Union
FOC	Fibre Optic Cables
HPA	Health Protection Agency
HVAC	High Voltage Direct Current
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
kV	kilovolt
NPS	National Policy Statement
NRPB	National Radiological Protection Board
NSIP	Nationally Significant Infrastructure Projects
OHID	Office for Health Improvements and Disparities
PHE	Public Health England

Term (acronym)	Definition
SCENIHR	European Commission's Scientific Committee on Emerging and Newly Identified Health Risks
WHO	World Health Organisation
WSCC	West Sussex County Council

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Rampion 2
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