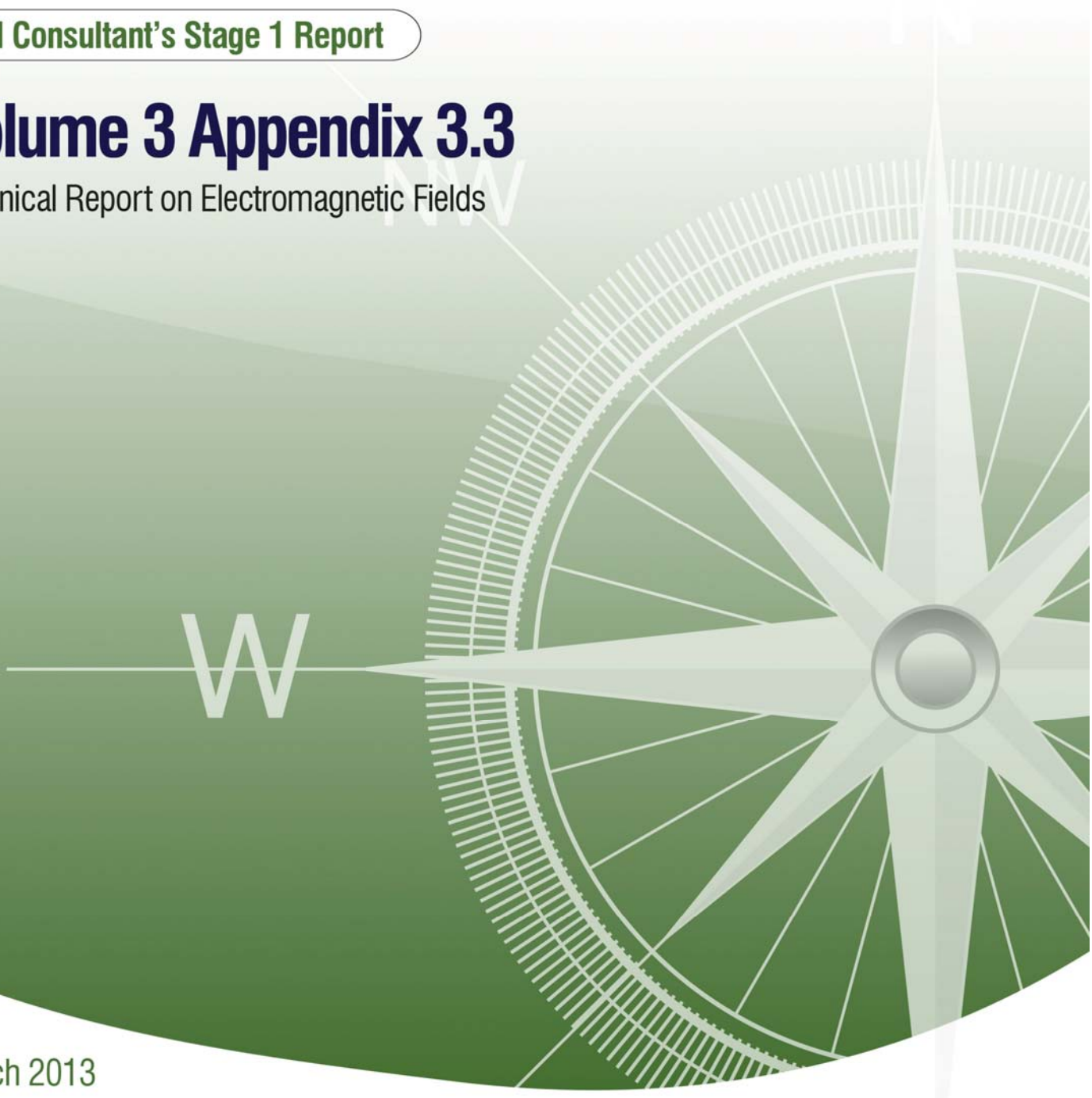
# The Grid West Project

EIRGRID

## Lead Consultant's Stage 1 Report

# Volume 3 Appendix 3.3

Technical Report on Electromagnetic Fields




March 2013

TOBIN Consulting Engineers

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# REPORT

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## DOCUMENT AMENDMENT RECORD

| | |
|---|---|
| **Client:** | **EirGrid** |
| **Project:** | **Grid West Project** |
| **Title:** | **Appendix 3.3 of Stage 1 Report –Technical Report on Electromagnetic Fields** |

| **PROJECT NUMBER: 6424** | | | | **DOCUMENT REF: 6424 Appendix 3.3 Technical Rep on EMF.doc** | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
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| | | | | | | | |
| A | Final issue | JS | 21/02/13 | JMcA | 21/02/13 | GC | 21/02/13 |
| **Revision** | **Description & Rationale** | **Originated** | **Date** | **Checked** | **Date** | **Authorised** | **Date** |
| **TOBIN Consulting Engineers** | | | | | | | |

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# EXECUTIVE SUMMARY

A key issue regarding the construction of a new electricity transmission line, such as the proposed 400kV Grid West project is in understanding if there are possible effects from the resulting electromagnetic fields (EMF) on human and animal health. EirGrid views the protection of the health, safety and welfare of its staff and the general public as a core company value and thereby ensures its projects are compliant with EMF exposure limits published by the International Commission on Non-Ionising Radiation Protection (ICNIRP). These guidelines are the most commonly recognised internationally and are used as the basis for the European Council Recommendation 1999/519/EC on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) [16].

There have been many thousands of research projects into possible health effects of the electric and magnetic fields created by power lines. There have been some studies that have suggested a weak statistical association between electric and magnetic fields and some cancers. However none of these studies has been able to demonstrate a causal link between the two [6]. To date there has been no conclusive evidence that electromagnetic fields at the levels associated with power lines cause any harmful effects to human health.

EirGrid closely monitors all new developments and research and presents its current position on the subject in set out in its information leaflet entitled '*EMF & You – General Information about Electric & Magnetic Fields in Ireland*', published in 2013 [20]. This document replaced the earlier publication, '*Information on Electric and Magnetic Fields'* [19] which was prepared in 2007. The purpose of this paper is to provide a technical review of the latest internationally published research and guidelines on the subject and to consider the implications of these on the Grid West project.

The research considered publications on the effects of extremely low frequency (ELF)[1] electric and magnetic fields since 2007, with particular focus on any new publications and guidelines issued by the internationally recognised agencies leading this research. These agencies are:

- World Health Organisation (WHO)
- Institution of Electrical and Electronic Engineers (IEEE)
- International Commission on Non-Ionising Radiation Protection (ICNIRP)
- International Agency for Research on Cancer (IARC)

There have not been any significant new findings that have resulted in the recommended exposure limits to electric and magnetic fields being reduced since 2007. The only significant change is that in 2010 the ICNIRP changed the guideline by raising the recommended exposure to magnetic fields from 100 μT to 200 μT. As magnetic fields associated with a single circuit 400kV line, as being considered for Grid West, are generally less than 10% of the lower recommended level (100 μT), this change to the ICNIRP guidelines does not have any impact on the Grid West scheme and will have the effect of ensuring that the lines operate within the guidelines by a greater margin.

[1] The 50Hz frequency of the electrical system operated in Ireland is defined as being extremely low frequency

It is not proposed that EirGrid design to this new higher limit of exposure to magnetic fields, but maintains the common international guidance of 100 μT (,i.e. more conservative). EirGrid has confirmed its intention to continue working to the 1998 ICNIRP guidelines for Reference Level of magnetic flux density.

In respect of electric fields, this report has found that, based on the reports referenced, a 400kV overhead line, built to current EirGrid standards complies with the Basic Restriction levels[2] as referenced in the ICNIRP report.

[2] Based on calculations of the Basic Restriction level in accordance with ICNIRP guidelines, as reported by Parsons Brinckerhoff and Associates [18] as carried out by Dimbylow (2005).

# 1 INTRODUCTION

The West of Ireland and County Mayo in particular has significant potential for the development of renewable generation, particularly wind and ocean energy (tidal/wave). EirGrid is planning to provide infrastructure to connect 647MW of wind energy from a number of wind farm developments in County Mayo, in the Bellacorick area. To accommodate these connections and as part of the EirGrid Grid25 strategy to develop the Irish electricity transmission system, EirGrid is planning a new electricity transmission line from the Bellacorick area (hereafter referred to as the Bellacorick node) to connect to the existing grid at either of the existing 220 kV substations at Flagford in County Roscommon or Cashla in County Galway. EirGrid's analysis of the requirements of this line has concluded that a new 400 kV line with associated substation at the Bellacorick node and extensions to the existing substation at either Flagford or Cashla will be required. This project is designated the Grid West project.

The Grid West project is currently in the development stage, leading to an application for planning consent to An Bord Pleanála. EirGrid has appointed consultants, TOBIN Consulting Engineers in association with URS, to develop this project and prepare the planning application.

One of the concerns the public may have regarding a new electrical power transmission project is the possible effect of electromagnetic fields (EMF) on health. EirGrid provide information to the public through their website; the primary document being an information leaflet entitled 'EMF & You – General Information about Electric & Magnetic Fields in Ireland' [20]. This document was published in early 2013.

The purpose of this paper is to provide a technical review of the latest internationally published research and guidelines on the subject and to consider the implications of these on the Grid West project.

# 2 SUMMARY OF RESEARCH AND FINDINGS

There are many sources of electromagnetic radiation, including power lines, radio and television transmitters, mobile telephones, microwaves, light, x-rays and gamma rays. These different radiations are characterised by their frequency, which varies from 50 Hz (cycles per second) to in excess of $10^{20}$Hz[3]. These are classified as non-ionising radiation at frequencies below $10^{15}$ Hz and as ionising radiation above $10^{15}$ Hz. In Ireland power lines operate at 50 Hz, which are classified as extremely low frequency fields. This paper only considers the effects of this extremely low frequency.

There are a number of internationally recognised agencies that typically provide the basis for guidelines for exposure to EMF. These are:

- World Health Organisation (WHO)
- Institution of Electrical and Electronic Engineers (IEEE)
- International Commission on Non-Ionising Radiation Protection (ICNIRP)
- International Agency for Research on Cancer (IARC)

The key publications from the above organisations that set out the findings on the effects of electric and magnetic fields and make recommendations on maximum exposure levels are:

- World Health Organisation: Electromagnetic fields and public health, Exposure to extremely low frequency fields fact sheet No. 322 (June 2007) [1]
- International Commission on Non-Ionizing Radiation Protection: ICNIRP guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz) published in: Health Physics 99(6):818-836 (2010 )[2]
- International Commission on Non-Ionizing Radiation Protection: ICNIRP guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz) published in: Health Physics 74(4): 494-522; (1998) [3]
- International Agency for Research on Cancer: IARC monographs on the evaluation of carcinogenic risks to humans. Volume 80 Non-ionizing radiation, part 1: static and extremely low-frequency (ELF) electric and magnetic fields [online] (2002). [4]

## 2.1 ICNIRP GUIDELINES 2010

Of the above documents, only that published by ICNIRP has had any significant revisions since 2007. The ICNIRP publication in 2010 has changed the guideline for the acceptable public exposure limit from 100μT[4] to 200μT. The 100μT guideline had been in force since 1998 and has been identified as still being generally used worldwide, notwithstanding the new guidance.

[3] $10^{20}$Hz is equivalent to one hundred billion billion cycles per second.
[4] 100 μT (micro-Tesla) is equivalent to one ten thousandth of one Tesla, the standard unit of measurement of magnetic fields

The EirGrid information leaflet 'EMF & You – General Information about Electric & Magnetic Fields in Ireland' [20] follows the more conservative of the ICNIRP 1998 and 2010 guidelines for Reference Levels of electric field strength and magnetic flux density. The ICNIRP guidelines were adopted by the EU in 1999 [17].

The ICNIRP Report of 2010 indicates the effect of electric fields on the human body varies as there are significant differences between individuals and within the body of an individual. ICNIRP adopts a conservative approach in drawing up the guidelines concerning electric fields, resulting in a number of different guidance levels for exposure to electric fields. Basic Reference Restrictions have been defined for Operational Exposure and General Exposure these are defined as:

- The Basic Restriction for General Public Exposure is that power frequency fields should not induce electric fields in the central nervous system (CNS) of the head (i.e. brain and retina) that exceed 20 mV/m [5].
- The Basic Restriction for Occupational Exposure of power frequency fields should not induce electric fields in the central nervous system of the head (i.e. brain and retina) that exceed 100 mV/m [18].

It is difficult to measure the electric field within the human body, so ICNIRP established "Reference Levels" which are obtained by calculation which correlate the external fields (which can be measured) with the field within the human body. The calculated Reference Level for General Public exposure is 5kV/m and Operational Exposure is 10kV/m. The reference levels represent the recommended maximum electric field strength exposure limit in each case. In these calculations a number of safety factors were applied with the intention that, where measured or calculated fields do not exceed these Reference Levels, compliance with the 'Basic Restriction' can be assumed, and further investigation is not be required. If the Reference Level is exceeded then further calculations should be done to confirm that the Basic Restriction is not exceeded. Applying the mathematical modelling methodology published by Dimbylow (1998, 2000 and 2005) to the 2010 ICNIRP Guidance the electric field value can attain a level of 9.9 kV/m without exceeding the basic restrictions.

In the Irish context, European Union (EU) directives are also potentially significant on the adoption of EMF reference levels. The EU has published a proposed directive on the minimum health and safety requirements regarding the exposure of workers to the risks arising from electromagnetic fields [16]. The field level limit for workers' exposure is called 'orientation value' which corresponds to the level where no adverse health effects should be noticed under normal working conditions for a person, not being part of a group at particular health risk. A second level is nominated within the regulations, the Action Value which represents the maximum directly measureable field for which automatic compliance with the exposure limit is guaranteed.

[5] ICNIRP altered the definition of the Basic Restrictions in the 2010 version of the guidelines. In the 1998 document the basic restrictions were provided on current density induced in the human head and trunk, while in the 2010 Guidelines they were provided on the internal electric field. This did not affect the recommendations for the Reference Levels and the reference levels for the electric field did not change between the 1998 and 2010 guidelines.

Table 2-1 below summarises the different recommended exposure limits set by ICNIRP [2] and the EU Directive [16].

**Table 2-1: Summary of EMF Exposure Guidelines**

| | | Basic Restrictions | | Reference Levels | | | |
|---|---|---|---|---|---|---|---|
| | | | | Electric Field (kV/m) | | Magnetic Field (μT) | |
| | | Occupational Exposure (mV/m) | Public Exposure (mV/m) | Occupational Exposure (kV/m) | General Public Exposure (kV/m) | Occupational Exposure (μT) | General Public Exposure (μT) |
| **ICNIRP** | | 100 (2010) | 20 (2010) | 10 (1998) | 5 (1998) | 500 (1998) | 100 (1998) |
| **EU** | Orientation Value (Safety& Health Effects) | 100 | - | 10 | - | 1000 | - |
| | Action Value (Health effects) | 800 | - | 20 | - | 13320 | - |

It should be noted that although the recommended exposure limits for the general public are lower than those set for people exposed to fields in the work place, the guidelines set by both ICNIRP and the EU for exposure limits in the workplace are still considered safe from both a health and safety perspective.

In a report prepared by Parsons Brinckerhoff and Associates (PB) for Northern Ireland Electricity and EirGrid in 2009 on the proposed Cavan-Tyrone and Meath-Cavan 400 kV transmission circuits [18], the authors calculated the electric fields associated with a 400 kV single circuit overhead transmission line built to EirGrid standards. The Grid West line could be similar to this line.

In the PB document it is reported that at maximum voltage (420 kV, i.e. including a 5% overvoltage) and maximum sag (9 metres clearance) [6], that the electric field for a 400 kV line would be 8.3kV/m. This is based on taking the readings at 1m above ground level.

It should be noted that the conditions described above represent a theoretical system operation scenario which in accordance with EirGrid's operating procedures is not likely to occur in reality. It does

[6] The strength of electric and magnetic fields vary with distance from the source, therefore minimum ground clearances are an important consideration in the specification of any new overhead line. EirGrid specify a minimum ground clearance of 9m, this is the minimum vertical distance a transmission line can be from the ground under the most onerous combination of design loadings.

however represent the maximum EMF conditions, whereas the likely operational conditions present lower electric and magnetic fields.

Given this value is higher than the 5 kV/m Reference Level for General Public Exposure as presented in Table 2-1 above, in accordance with ICNIRP 2010, further calculation should be undertaken to assure compliance with the Basic Restriction. As noted above, calculations show that the Basic Restriction is not exceeded if the electric field is less than 9.9 kV/m.

## 2.2 OTHER RESEARCH SINCE 2007

The other significant research that has been published or ongoing since 2007 includes the following:

- One of the key publications in the Irish context since 2007 has been the publication in 2010 by the Office of the Chief Scientific Advisor to the Government of Ireland: *A Review of Recent Investigations into the Possible Health Effects of Exposure to Electromagnetic Fields (EMF) from Power Lines (paper prepared by Professor Denis O'Sullivan)* [6]

  This paper concluded that there is no scientifically conclusive evidence that exposure to the low levels of magnetic fields associated with power lines causes cancer. The paper also noted the work of the ICNIRP and that the exposure limits set in the guidelines published by this organisation have been adopted by many countries including Ireland.

  This paper also records that '*The investigation of human exposure to electric fields has not been considered with the same interest, in the absence of any evidence of significant impact to date. However, indirect effects have been reported due to the increased deposition of charged airborne particles in the respiratory system caused by the presence of large AC electric fields in the vicinity of power lines. A detailed study of the proposed mechanism has been carried out and the suggestion has been rejected.*'

  This statement is consistent with the guidance from ICNIRP and other international organisations that there is no conclusive evidence that exposure to electric fields at the levels shown in Table 2-1 causes any harmful health effects.

- World Health Organisation (WHO)
  There is a team of people working on the WHO International EMF project. This team was established in 1996 to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz. The latest progress report published by this group was in May 2010-2011 [7] and did not report any significant new findings. The group has not found it necessary to revise the WHO guidance documentation [1]

In addition there were several publications in the UK concerning optimal phasing of double circuit transmissions lines to minimise EMFs. As the proposed Grid West transmission line is a single circuit this recommendation would not apply.

# 3 RECOMMENDATIONS

There have not been any significant new findings that have resulted in the recommended exposure limits to electric and magnetic fields being made more stringent since October 2007. No further publications have been made that provide, internationally recognised, conclusive evidence that very low frequency electromagnetic fields are harmful to humans or animals at the exposure levels caused by high voltage power lines. A significant change is that the ICNIRP guidelines have changed the recommended exposure to magnetic fields from 100 µT to 200 µT, (i.e. less conservative) per table 7 of the 1998 report and table 4 of the 2010 report. EirGrid have confirmed their intention to continue working to the more onerous 1998 ICNIRP guidelines. As the magnetic fields associated with a single circuit 400kV line, as is being considered for Grid West, are generally less than 10% of the lower recommended level, this change does not have any impact on the Grid West project.

In respect of electric fields, this report found evidence that a 400kV overhead line, built to current EirGrid standards complies with the Basic Restriction[7] levels as referenced in the ICNIRP guidelines.

[7] Based on calculations of the Basic Restriction level in accordance with ICNIRP guidelines, reported by Parsons Brinckerhoff and Associates [18] as carried out by Dimbylow (2005).

# ANNEX 1

## Bibliography

## ANNEX 1: BIBLIOGRAPHY


[1] World Health Organisation, *Electromagnetic fields and public health, Exposure to extremely low frequency fields fact sheet No. 322* (June 2007), [online] Available at: http://www.who.int/mediacentre/factsheets/fs322/en/index.html [accessed 8th March 2012].

[2] International Commission on Non-Ionizing Radiation Protection ICNIRP, *ICNIRP guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz) published in: Health Physics 99(6):818-836* [online] (2010) Available at: http://www.icnirp.de/documents/LFgdl.pdf [accessed 8th March 2012]

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[6] Office of the Chief Scientific Adviser to the Government of Ireland, *A review of recent investigations into the possible health effects of exposure to electromagnetic fields (EMF) from power lines* [online] (July 2010) Available at: http://www.c-s.ie/media/EMF_Denis%20O'Sullivan_11Feb2011_revised.pdf [ Accessed on 20th March 2012]

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[9] Department of Health, *Government response to Stakeholder Advisory Group on extremely low frequency electric and magnetic fields (ELF EMFs) (SAGE) recommendations* [online] (October 2009) Available at: http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_107124 [ accessed 8th March 2012]

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[13] Department of Energy and Climate Change, *Codes of practice on optimum phasing for high voltage power lines* [online] Available at: http://www.decc.gov.uk/en/content/cms/meeting_energy/consents_planning/codes/codes.aspx [accessed 8th March 2012]

[14] Energy Networks Association (ENA) site maintained by National Grid, *400 kV underground cables: magnetic fields* [online] Available at: http://www.emfs.info/Sources+of+EMFs/Overhead+power+lines/specific/400+kV+underground+magnetic.htm [accessed 8th March 2012]

[15] Energy Networks Association (ENA) site maintained by National Grid, *Power lines: specific voltages* [online] Available at: http://www.emfs.info/Sources+of+EMFs/Overhead+power+lines/specific/ [Accessed 8th March 2012]

[16] DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL On the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (Directive within the meaning of Article 16(1) of Directive 89/391/EEC) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0348:FIN:EN:PDF

[17] European Union, COUNCIL RECOMMENDATION of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC)

[18] Parsons Brinckerhoff and Associates, CAVAN-TYRONE AND MEATH-CAVAN 400KV TRANSMISSION CIRCUITS: COMPARISON OF HIGH VOLTAGE TRANSMISSION OPTIONS: ALTERNATING CURRENT OVERHEAD AND UNDERGROUND, AND DIRECT CURRENT UNDERGROUND (February 2009) http://www.nie.co.uk/documents/NS/T-C-Inter_H-Safety/7-PB-Final-Report-FEB-2009.aspx

[19] EirGrid, Information on Electric and Magnetic Fields (2007)
http://www.eirgrid.com/media/Electro%20Magnetic%20Fields%20-%20EMF.pdf

[20] EirGrid, EMF & You – General Information about Electric & Magnetic Fields in Ireland (2013)

# ANNEX 2

## Technical Papers Reference List

## ANNEX 2: TECHNICAL PAPERS REFERENCE LIST

The following list includes documents which the Grid West team considered would be beneficial in developing this paper. This list is representative of documents identified and is not to be considered as a complete list of all reference documents.

These documents were reviewed for relevance and where appropriate used as reference documents for the preparation of this report.

Documentation sourced from EirGrid's existing documentation

- Transmission Constraint Groups Valid from 10th June 2011
- Operating Security Standards April 2010
- Assessment of the technical issue related to significant amounts of EHV Underground Cable in the All-island Electricity Transmission System – Tokyo Electric Power Company November 2009
- Grid 25: A Strategy for the development of Ireland's Electricity Grid for a Sustainable and Competitive Future (particularly Appendix A: Technical Options for Grid Development
- Transmission Forecast Statement 2011 -2017. http://www.eirgrid.com/aboutus/publications/transmissionforecaststatement2011-2017/
- Transmission Development Plan 2010 (Draft for Public Consultation) http://www.eirgrid.com/media/TDP%202010%20Final%20Draft%20for%20Public%20Consultation%20v3.pdf
- All Island Generation Capacity Statement 2012 -2021
- All island Transmission Map
- UCTE Letter to APG dated 2008-01-14
- EirGrid Grid Code
- The Electricity Regulations ACT 1999 and subsequent amendments
- SI No.60 European Communities (Internal Market in Electricity) Regulations 2005
- Note of the DG Energy & Transportation on directive 2003/54/EC And 2003/55/EC On The Internal Marker In Electricity and Natural Gas
- EU Directive 2001/77/EC - Promotion of electricity produced from renewable energy sources in the internal electricity market
- EirGrid: Information on Electrical and Magnetic Fields October 2007
- Electric Field Simulations, PB, November 2011

Documentation Sourced from Alternative External Locations

- Study on the Comparative merits of overhead electricity transmission lines versus underground cables – Golder Associates 2008
- Study of High Voltage AC Underground Cable Systems - F. Faria da Silva, Claus L. Bak, Wojciech T. Wiechowski 4th November 2008

- World Health Organisation – various publications on the effects of EMF (Note: only recently issued fact sheet is for radiation from mobile phones. The current fact sheet at power system frequencies pre-dates the EirGrid publication)
- IEEE Standards Coordinating Committee 28. IEEE standard for safety levels with respect to human exposure to electromagnetic fields, 0-3 kHz. New York, NY, IEEE - The Institute of Electrical and Electronics Engineers, 2002 (IEEE Std C95.6-2002).
- National Grid 400kV Underground Cable Construction: Presentation by Tim Inglehearn
- Innovative Solutions for Overhead Line Supports, CIGRE, Ref 416 and 416A, Working Group B2-08, January 25 2010.
- Office of the Chief Scientific Officer for the Irish Government, A Review into Recent Investigations into the Possible Health Effects of Exposure to Electromagnetic Fields (EMF) from Power Lines.
- Government White Paper – Delivering a Sustainable Energy Future for Ireland http://www.dcenr.gov.ie/Energy/Energy+Planning+Division/Energy+White+Paper.htm
- EMFs.info, Electric and Magnetic Fields. http://emfs.info

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