Appendix to Chapter 12: Air

Appendix 12.3 Explanation and Modelling of Electromagnetic Fields

The data and descriptions in this appendix have informed the cumulative evaluations in the EIA Main Report.

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A12.1 EXPLANATION AND MODELLING OF ELECTROMAGNETIC FIELDS

A12.3.1 Explanation of Electric Fields and Magnetic Fields

Electrical objects and anything connected to them produce two types of fields - electric fields and magnetic fields. The term "field" is used to describe the way an object influences its surrounding area. A temperature field, for example, surrounds a warm object, such as a space heater. EMF's surround any object that is generating, transmitting or using electricity, including appliances, wiring, office equipment, generators, batteries and any other electrical devices. EMFs are invisible and they cannot be felt or heard.

Electric fields occur as a result of the electric potential (or voltage) on these objects, and magnetic fields occur as a result of electric current flowing through these objects. Just like a temperature field, electric and magnetic fields can be measured and their levels depend on, among other things:

- Characteristics of the source of the field (voltage, current, cable configuration and formation); and
- Distance from the source of the field.

The Electric Field is measured in volts per metre (V/m) or (kV/m). Magnetic Fields are measured in microtesla (µT). Electric Fields and Magnetic Fields are highest closest to the source and their level reduces quickly with distance from the source. This is similar to the way that the heat from a candle or campfire weakens as you move farther away. Although ordinary objects do not block magnetic fields, electric fields can be easily blocked by objects such as trees and buildings.

All sources of EMF below 300 GHz in the electromagnetic spectrum (such as the subject development) are considered Non-Ionizing Radiation, which means the EMF does not carry enough energy to remove an electron from its atomic structure.

A-12.3.1.1 Electromagnetic Fields in the Natural Environment

Both electric and magnetic fields occur naturally in our environment and even in our own bodies as part of the normal functioning of our cardiac and nervous systems. There is a natural electric field at the earth's surface that is created by electric charges in the upper atmosphere, also known as the ionosphere. During fair weather, these electric field levels vary between 100 and 150 volts per meter (V/m) over flat surfaces. During stormy weather, on the other hand, storm clouds often contain large quantities of electric charge, and the electric field may reach intensities up to 20,000 V/m over flat surfaces and can be considerably higher above hillocks or near the tops of objects such as trees. The Earth's magnetic field, which is due mainly to currents circulating in the outer layer of the Earth's core, extents from the Earth's core out into space. Its magnitude at the Earth's surface varies between about 30 µT (microTesla) at the equator and about 60 µT at the poles.

Such naturally occurring electric and magnetic fields do not change direction and are, therefore, referred to as static or direct current (DC) fields. Naturally occurring electric and magnetic fields differ from the extremely low frequency electromagnetic Fields (ELF-EMF) produced by the power system, which fluctuate at a fixed frequency and are referred to as alternating current (AC) fields. For this reason, the existing levels of naturally occurring static EMF fields are not taken into account in the UWF Grid Connection EIA Report.

A-12.3.1.2 Electromagnetic Fields in the Built Environment

In the built environment, man-made sources of EMF include the power system and communication networks. In Ireland, the AC electric and magnetic fields produced by the power system vary at a frequency of 50-Hertz (Hz) (i.e. the fields alternate direction and intensity back and forth 50 times each second). Electric and magnetic fields are produced in all residential and working environments as a result of nearby electrical wiring, appliances, power lines and telecommunication masts, among other things. A comparison of electric and magnetic fields from 110kV electrical power system infrastructure with the typical electric and magnetic fields emitted by common household appliances is included in Section A-12.3.2. In summary this comparison demonstrates that in many cases, residential electrical appliances and tools can generate higher magnetic and electric fields in their close proximity (30cm) than at either the fence of an 110kV substation compound or directly above 110kV underground cables.

In a recent study of homes in the UK, most of homes had average magnetic field levels in the range 0.2µT to 0.4µT which were attributed to low voltage sources (i.e., wiring, appliances, and distribution circuits) (Mastanyi et al, 2007). Electric field measurements in residential environments, average exposures were found to be less than 10 V/m (Bracken et al, 1990)

A12.3.2 Typical Electric and Magnetic Fields in Residential and Working Environments

Field measurements, carried out by CEI, of the electric fields and magnetic fields near 110kV substations and underground cables are shown below in Table 1 and Table 2.

Table 1 Electric Fields measured from electrical power system infrastructure

Electrical power system	0 meter distance[1] (V/m)	30 meters distance (V/m)	100 meters distance (V/m)	ICNIRP Limit
110kV Substation	40	20	Less than 1	5000 V/m
110kV Underground Cables[2]	n/a	n/a	n/a	5000 V/m

Table 2 Magnetic Fields measured from electrical power system infrastructure

Electrical power system	0 meter distance (µT)	30 meters distance (µT)	100 meters distance (µT)	ICNIRP Limit
110kV Substation	1	0.4	Less than 0.01	100µT
110kV Underground Cables[3]	10 (See footnote 3)	Less than 0.1	Less than 0.05	100µT

Measurements of the typical electric and magnetic fields near domestic appliances are shown in Table 3 and Table 4 below.

Table 3 Typical Electric Fields Household Appliances

Electric appliance	Electric field strength (V/m) at 30cm	ICNIRP Limit
Stereo receiver	180	**5000 V/m**
Iron	120	**5000 V/m**
Refrigerator	120	**5000 V/m**
Mixer	100	**5000 V/m**
Toaster	80	**5000 V/m**
Hair dryer	80	**5000 V/m**
Colour TV	60	**5000 V/m**
Coffee machine	60	**5000 V/m**
Vacuum cleaner	50	**5000 V/m**
Electric oven	8	**5000 V/m**
Light bulb	5	**5000 V/m**

[1] A distance of 0 m corresponds to the central point above the underground cable, or at the substation fence.
[2] There is no electric field above ground level for underground cables, as the soil, earth materials and metallic sheath, which surrounds each cable, removes the potential for electric fields outside the cable.
[3] Scaled to reflect similar level expected based on the maximum MVA load 155MW for the grid connection.

Table 4 Typical Magnetic Fields Household Appliances

Electric appliance	3 cm distance (µT)	30 cm distance (µT)	1 m distance (µT)	ICNIRP Limit
Hair dryer	6 – 2000	0.01 – 7	0.01 – 0.03	**100µT**
Electric shaver	15 – 1500	0.08 – 9	0.01 – 0.03	**100µT**
Vacuum cleaner	200 – 800	2 – 20	0.13 – 2	**100µT**
Fluorescent light	40 – 400	0.5 – 2	0.02 – 0.25	**100µT**
Microwave oven	73 – 200	4 – 8	0.25 – 0.6	**100µT**
Electric oven	1 – 50	0.15 – 0.5	0.01 – 0.04	**100µT**

The ICNIRP limit[4] for EMF exposure for electric fields is 5000 V/m. As can be seen from Table 3, the typical exposure levels from common household appliances are below and in compliance with the ICNIRP limits in close proximity to the appliance. For example, an operational refrigerator can expose the user or resident to 120 V/m at a distance of 30cm from the appliance. Any exposure to electric fields at this level is typically for momentary or brief periods at any one time.

The ICNIRP limit[5] for EMF exposure for magnetic fields is 100µT. Low voltage sources, such as home appliances, contribute significantly to our overall exposure to magnetic fields. In a recent study of homes in the UK, for example, 77% of homes had average magnetic field levels above 0.2 µT and 57% of homes had average magnetic field levels above 0.4 µT which were attributed to low voltage sources (i.e., wiring, appliances, and distribution circuits) (Mastanyi et al, 2007). The typical[6] magnetic fields which people can be exposed to, at various distances from electrical equipment and appliances, in residential and public premises are presented in Table 4. As can be seen from Table 4, the use of a vacuum cleaner can expose the user to 200µT at a distance of 3cm and up to 20µT at a 30cm distance from the appliance.

While the comparison between operational 110kV substations or underground cables and domestic appliances provides valuable perspective, and indeed demonstrate that some common household appliances breaches the ICNIRP limit at very close proximity, it is limited by several differences between power lines and appliances. First, electric and magnetic fields are only associated with appliances for the duration that the appliance or tool is in use, while power lines are typically in service at all times. Furthermore, the field levels from appliances drop off at a faster rate with distance, compared to electricity transmission networks.

[4] http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf
[5] http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf
[6] Source: http://www.who.int/peh-emf/about/WhatisEMF/en/index3.html

A12.3.3 Criteria for Modelling Theoretical Worst-Case Effects

In order to categorically demonstrate that the maximum possible power load of the electric cables and equipment associated with the UWF Grid Connection, and associated with the Other Elements - UWF Related Works and the Upperchurch Windfarm, will comply with the EU EMF Exposure Recommendations and the ICNIRP limits, the theoretical worst-case contribution of the various electrical plant to EMF levels in the environment is evaluated in this report. The worst-case levels of EMF have been modeled using the criteria outlined in Table 5, the results of the modelling are summarized in Table 6.

Table 5 Criteria for modelling theoretical worst-case effects

Whole UWF Project Element	Worse-Case Scenario Criteria
UWF GRID CONNECTION	
Mountphilips Substation	The closest piece of electrical apparatus from the Substation Compound perimeter fence is 5m. The worst case scenario EMF from the equipment in the compound is modelled from the perimeter fence, and is referred to throughout this report as the measurement of EMF at '0 meters'
End Masts Underground Cables	EMF from the underground 110kV cables which will loop the Mountphilips 110kV Substation onto the existing OHL, via the 2 No. End Masts, was modelled using: an electrical current of 1149 Amps based on the maximum possible power load, which is the winter power load of 219 MVA and 120 kV maximum voltage variation as specified by EirGrid.
Mountphilips – Upperchurch 110kV Underground Cables (UWF Grid Connection)	The maximum capacity possible of the electricity which the 110kV Mountphilips – Upperchurch UWF Grid Connection will be capable of delivering – i.e. 155 MW, and the associated electrical current of 856 Amps. It should be noted that this is the maximum possible power load for the electrical cables and has been modelled to demonstrate categorically compliance with the EU EMF Exposure Recommendation. The configuration of the cable design is the worst case flat configuration where the cable passes over existing services, which is a flat formation cable design (rather than trefoil formation), and therefore less cancelation of magnetic fields between cables. The minimum distance between the cables and the ground surface using this flat formation – i.e. 0.45m.
UWF RELATED WORKS	
Internal Windfarm Cables	The maximum capacity possible of the electricity which a 33kV wind turbine cable will be capable of delivering – i.e. 32 MW, and the associated electrical current of 280 Amps. And at the Consent Windfarm Substation there are two cable sets routed adjacent to each other, into the Substation, with a combined maximum of 64MW. It should be noted that this is the maximum possible power load for the electrical cables and has been modelled to demonstrate categorically compliance with the EU EMF Exposure Recommendation. The configuration of the cable design is the trefoil configuration. The minimum distance between the cables and the ground surface using this flat formation – i.e. 0.8m.
UPPERCHURCH WINDFARM	
Consented UWF Substation	The closest piece of electrical apparatus from the Substation Compound perimeter fence is 5m. The worst case scenario EMF from the equipment in the compound is modelled from the perimeter fence, and is referred to throughout this report as the measurement of EMF at '0 meters'
Consented UWF Turbines	The closest distance of a member of the public to electrical parts – i.e. at ground level, right beside the turbines (0m distance)

The results of this modelling (see Table 5 and Sections A-12.3.4 to A-12.3.7) demonstrate that the electric field and magnetic field emissions from the Mountphilips 110kV Substation, 110kV UWF Grid Connection, Consented UWF Turbines, Internal Windfarm Cable and Consented UWF Substation will be at a level **substantially less the ICNIRP limit of 5000 V/m and 100μT respectively.** Furthermore, the magnetic field levels will rapidly dissipate with increasing distance from the source.

A-12.3.3.1 Summary of Modelling Results

Table 6 Summary of Worst-case Scenario EMF Modelling Results

Whole UWF Project Elements	**Electric Fields**	**Magnetic Fields**
Mountphilips 110kV Substation	Electric fields will be very low due to the shielding which will be provided by the extensive metalwork within the substation compound, which will include electrical equipment housings, steelwork, the control building and metal palisade perimeter fence. Immediately outside the perimeter fence, the **worst-case EMF** from the substation are expected to be **40 V/m.**	Magnetic fields will be very low due to the shielding which will be provided by the extensive metalwork within the substation compound, which will include electrical equipment housings, steelwork, the control building and metal palisade perimeter fence. Immediately outside the perimeter fence, the **worst-case EMF** from the substation are expected to be **1µT**
Mountphilips – Upperchurch 110kV UWF Grid Connection (UWF GC)	The electric fields generated by the underground cables will be *completely screened* by the earth materials such as soil and a metallic sheath which will surround each cable, and **no electric fields** will be emitted above ground.	Directly above the UWF Grid Connection, the **maximum possible level** of the magnetic fields, generated by the underground cables, will be **54 µT**
Consented UWF Turbines	The electric field generated by the transformer, generator and cables are screened internally by the housing over the generator, and by the steel turbine tower. The turbine's transformer and generator are also at a substantial height above ground level and **will not contribute to the ambient electric field levels**.	Magnetic fields will be very low due to the shielding which will be provided by the extensive metalwork within the substation compound, which will include turbine housings and steelwork. The turbine and transformer are also at a substantial height about ground level. Right beside the turbine, worst case EMF are expected to be **0.2µT**[7]
Internal Windfarm Cables	The electric fields generated by the underground cables will be *completely screened* by the earth materials such as soil and a metallic sheath which will surround each cable, and **no electric fields** will be emitted above ground.	Directly above the Internal Windfarm Cables, the maximum level of the magnetic fields, generated by the underground cables, will be **7.6µT**
Consented UWF Substation	Electric fields will be very low due to the shielding which will be provided by the extensive metalwork within the substation compound, which will include electrical equipment housings, steelwork, the control building and metal palisade perimeter fence. Immediately outside the perimeter fence, the worst-case EMF from the substation are expected to be **40 V/m.**	Magnetic fields will be very low due to the shielding which will be provided by the extensive metalwork within the substation compound, which will include electrical equipment housings, steelwork, the control building and metal palisade perimeter fence. Immediately outside the perimeter fence, the worst-case EMF from the substation are expected to be **1µT.**

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A12.3.4 Worst Case EMF emissions from the UWF Grid Connection

The electric fields and magnetic fields were modelled, at various distances from electrical plant, using worst-case scenario criteria outlined in Table 5. The results of the modelling in relation to the 110kV Mountphilips Substation, Cables on End Masts and the 110kV UWF Grid Connection are presented in Table 7 (electric fields) and Table 8 (magnetic fields), and Plate 2.

Table 7 Contribution to ambient electric fields (worst case scenario) by the UWF Grid Connection

UWF Grid Connection	Distance from operational electrical apparatus or cables (m)	Existing Ambient Electric Fields (V/m)[8]	Worst Case Electric Field Contribution from the UWF Grid Connection (V/m)	Predicted Worst Case Ambient Electric Field levels during the operation stage (V/m)[9]	ICNIRP Guideline Limit (V/m)
Substation Compound	0m	less than 1	40	41	5000
Substation Compound	30m	less than10	20	30	5000
Substation Compound	100m	less than 20	less than 1	21	5000
Cables on End Masts	0m	less than 20	1,040	1060	5000
Cables on End Masts	30m	less than 50	50	100	5000
Cables on End Masts	100m	less than 100	less than 10	110	5000
Mountphilips to Upperchurch 110kV GC	0m	less than 1	None	No increase	5000
Mountphilips to Upperchurch 110kV GC	30m	less than 1	None	No increase	5000
Mountphilips to Upperchurch 110kV GC	100m	less than 1	None	No increase	5000

Table 8 Contribution to ambient magnetic fields (worst case scenario) by the UWF Grid Connection

UWF Grid Connection	Distance from operational electrical apparatus or cables (m)	Existing Ambient Magnetic Fields (µT)[10]	Worst Case EMF Contribution from the UWF Grid Connection (µT)	Predicted Worst Case Ambient EMF levels during the operation stage (µT)	ICNIRP Guideline Limit (µT)
Substation Compound	0m	0.05	1	1.05	100
Substation Compound	30m	0.02	0.4	0.42	100
Substation Compound	100m	0.07	0.16	0.23	100
Cables on End Masts	0m	0.01	35	35.01	100
Cables on End Masts	30m	0.04	1.3	1.34	100
Cables on End Masts	100m	0.1	0.1	0.2	100
Mountphilips to Upperchurch 110kV GC	0m	0.2	54	54.2	100
Mountphilips to Upperchurch 110kV GC	30m	0.2	0.13	0.33	100
Mountphilips to Upperchurch 110kV GC	100m	0.2	0.01	0.21	100

[8] Assumption: Information based on distances approaching the existing 110 kV OHL to the west of the proposed substation
[9] Assumption: Electric fields are cumulative which is unlikely
[10] Assumption: Information based on distances approaching the existing 110 kV OHL to the west of the proposed substation

A12.3.5 Worst Case EMF emissions from the Upperchurch Windfarm

In order to facilitate a cumulative evaluation of the Whole UWF Project, the electric fields and magnetic fields were modelled, at various distances from Upperchurch Windfarm electrical plant, using worst-case scenario criteria outlined in Table 5. The results of the modelling in relation to the Consented UWF Substation and the Consented UWF Turbines are presented in Table 9 (electric fields) and Table 10 (magnetic fields).

Table 9: Contribution to ambient electric fields (worst case scenario) by the Upperchurch Windfarm

Upperchurch Windfarm part	Distance from operational electrical apparatus or cables (m)	Existing Ambient Electric Fields (V/m)	Worst Case Electric Field Contribution from the Upperchurch Windfarm (V/m) [11]	Predicted Worst Case Ambient Electric Field levels during the operation stage (V/m)	ICNIRP Guideline Limit (V/m)
Consented UWF Substation (compound)	0m	less than 1	40	41	5000
Consented UWF Substation (compound)	30m	less than10	20	30	5000
Consented UWF Substation (compound)	100m	less than 20	less than 1	21	5000
Consented UWF Turbines	0m	less than 1	none	less than 1	5000
Consented UWF Turbines	30m	less than 1	none	less than 1	5000
Consented UWF Turbines	100m	less than 1	none	less than 1	5000

Table 10 Contribution to ambient magnetic fields (worst case scenario) by the Upperchurch Windfarm

Upperchurch Windfarm part	Distance from operational electrical apparatus or cables (m)	Existing Ambient Magnetic Fields (μT)	Worst Case EMF Contribution from the Upperchurch Windfarm (μT) [12]	Predicted Worst Case Ambient EMF levels during the operation stage (μT)	ICNIRP Guideline Limit (μT)
Consented UWF Substation (compound)	0m	0.05	1	1.05	100
Consented UWF Substation (compound)	30m	0.02	0.4	0.42	100
Consented UWF Substation (compound)	100m	0.07	0.16	0.23	100
Consented UWF Turbines	0m	0.2	0.2	0.4	100
Consented UWF Turbines	30m	0.2	0.07	0.27	100
Consented UWF Turbines	100m	0.2	0.07	0.27	100

[11] The electric field generated by turbine's transformer and generator are screened by the housing so will not contribute to the ambient electric field levels.

[12] Scaled to reflect similar level expected based on the expected MVA load from the Consented UWF Turbines.

A12.3.6 Worst Case EMF emissions from the UWF Related Works

The electric fields and magnetic fields were modelled, at various distances from UWF Related Works electrical plant, using worst-case scenario criteria outlined in Table 5. The results of the modelling in relation to the Internal Windfarm Cabling are presented in Table 11 (electric fields) and Table 12 (magnetic fields).

Table 11 Contribution to ambient electric fields (worst case scenario) by the UWF Related Works

UWF Related Works Relevant Electrical Plant	Distance from operational electrical apparatus or cables (m)	Existing Ambient Electric Fields (V/m)	Worst Case Electric Field Contribution from the Internal Windfarm Cabling (V/m)	Predicted Worst Case Ambient Electric Field levels during the operation stage (V/m)	ICNIRP Guideline Limit (V/m)
Internal Windfarm Cabling	0m	less than 1	None	No increase	5000
Internal Windfarm Cabling	30m	less than 1	None	No increase	5000
Internal Windfarm Cabling	100m	less than 1	None	No increase	5000

Table 12 Contribution to ambient magnetic fields (worst case scenario) by the UWF Related Works

UWF Related Works Relevant Electrical Plant	Distance from operational electrical apparatus or cables (m)	Existing Ambient Magnetic Fields (μT)	Worst Case EMF Contribution from the Internal Windfarm Cabling (μT)	Predicted Worst Case Ambient EMF levels during the operation stage (μT)	ICNIRP Guideline Limit (μT)
Internal Windfarm Cabling	0m	0.2	7.6	7.8	100
Internal Windfarm Cabling	30m	0.2	0.03	0.23	100
Internal Windfarm Cabling	100m	0.2	0.003	0.203	100

A12.3.7 Worst Case EMF emissions from Other Projects

In order to facilitate a cumulative assessment of the UWF Grid Connection with Other UWF Projects/Activities in the area, the existing Killonan to Nenagh 110kV Overhead Line, the Shannonbridge to Killonan 220kV Overhead Line and the potential Castlewaller Windfarm grid connection (underground cable) .

The worst case scenario electric fields and worst case magnetic fields associated with these three projects are illustrated on Plates 3 - 6 below.

A-12.3.7.1 Worst Case EMF emissions from Killonan – Nenagh 110kV Overhead Line

Worst Case Magnetic Fields - Killonan – Nenagh 110kV Overhead Line:

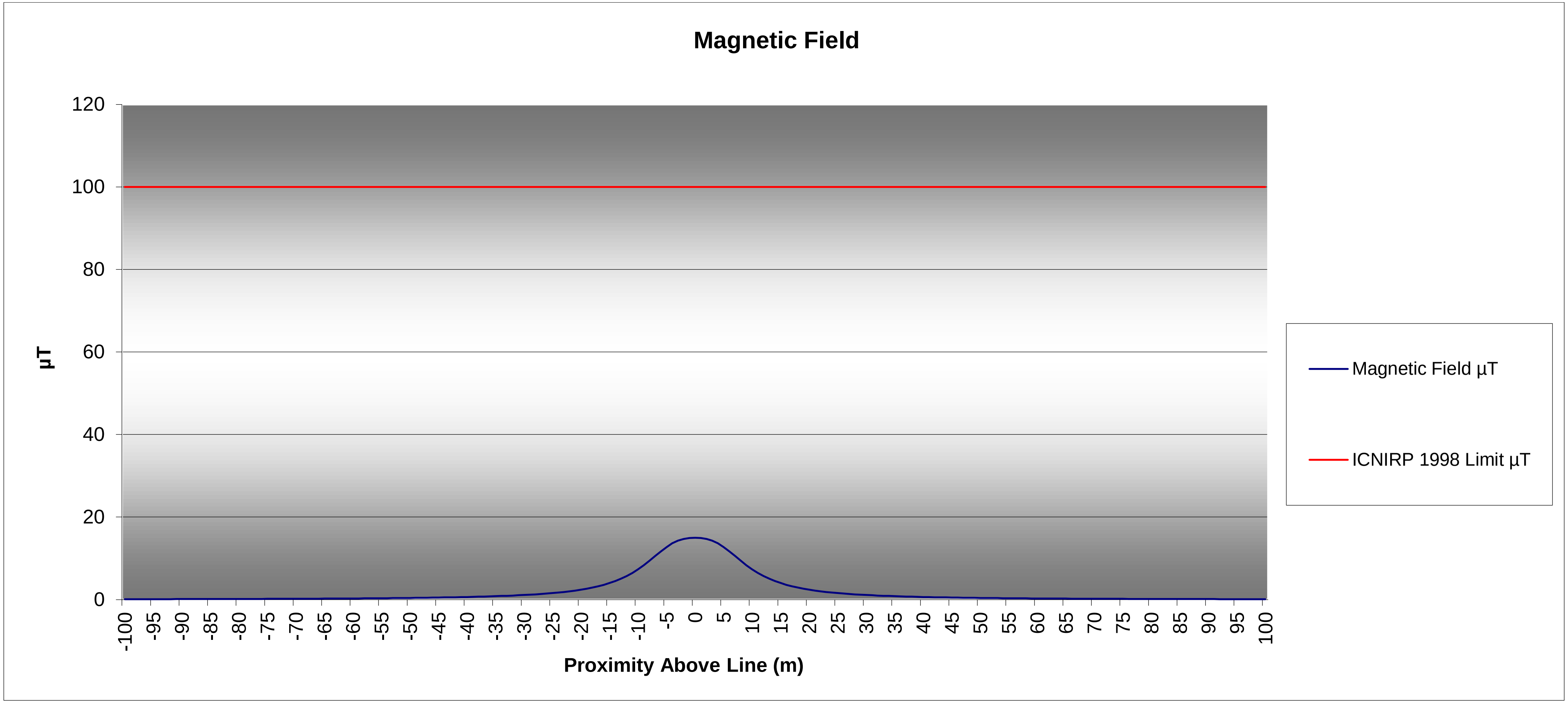

Plate 1: Maximum Possible Magnetic Field from the 110 kV OHL Cables (modelled at 127 MW)

Worst Case Electric Fields - Killonan – Nenagh 110kV Overhead Line:

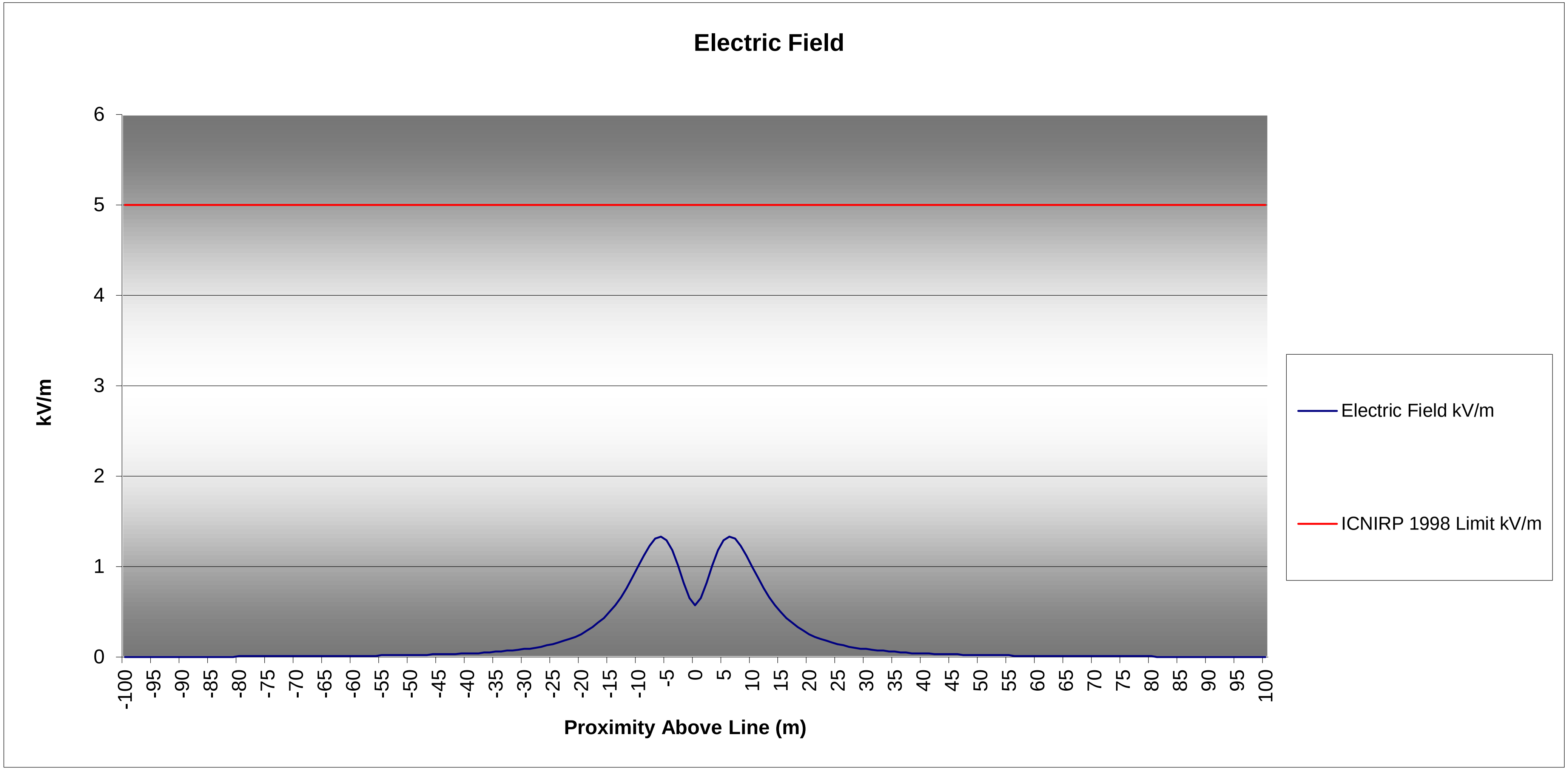

Plate 2: **Maximum Possible Electric Field from the 110 kV OHL Cables (modelled at 127 MW)**

A-12.3.7.2 Worst Case EMF emissions from Shannonbridge to Killonan 220kV Overhead Line

Worst Case Magnetic Fields - Shannonbridge to Killonan 220kV Overhead Line:

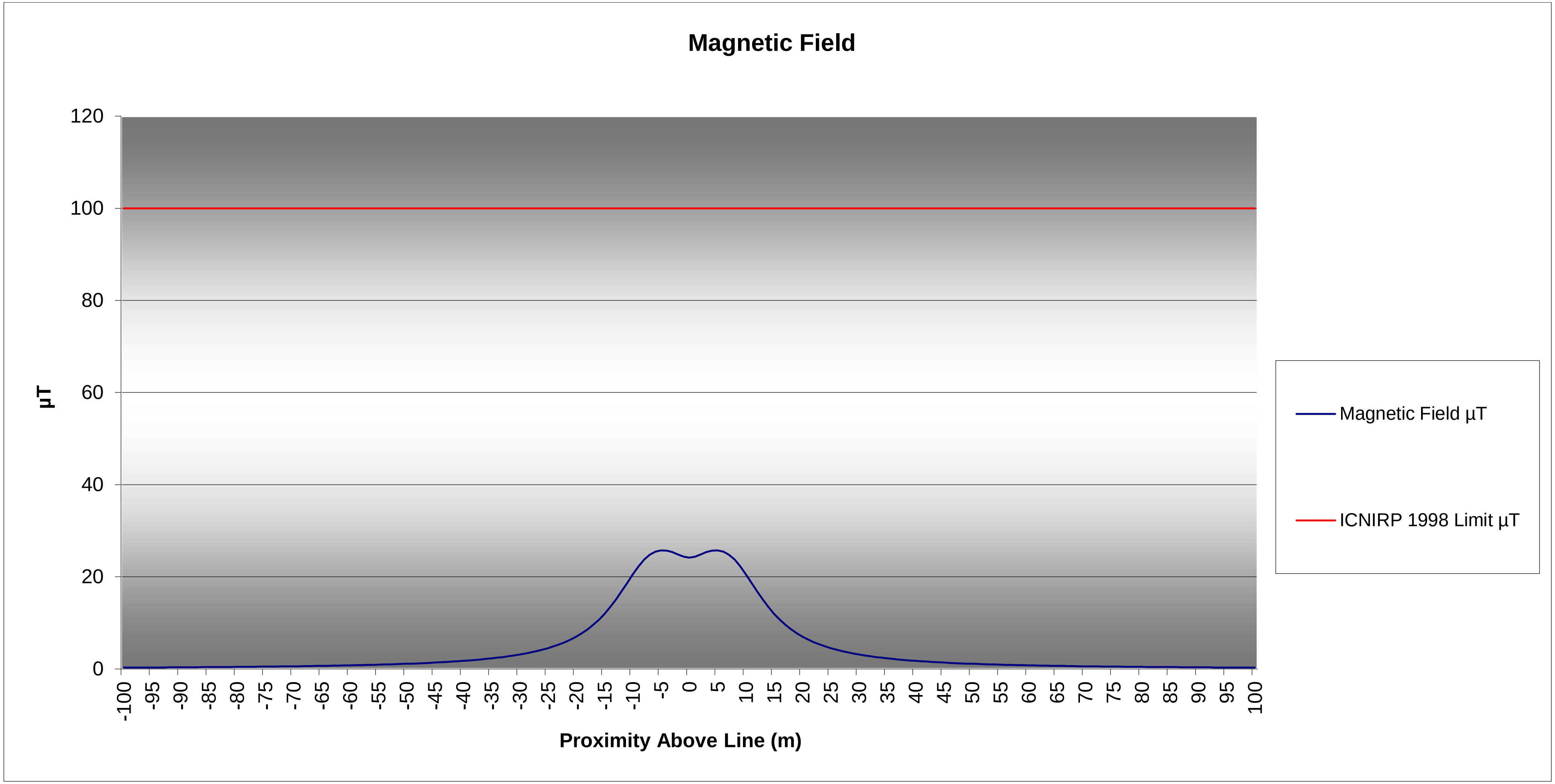

Plate 3: Maximum Possible Magnetic Field from the 220 kV OHL Cables (modelled at 376 MW)

Worst Case Electric Fields - Shannonbridge to Killonan 220kV Overhead Line:

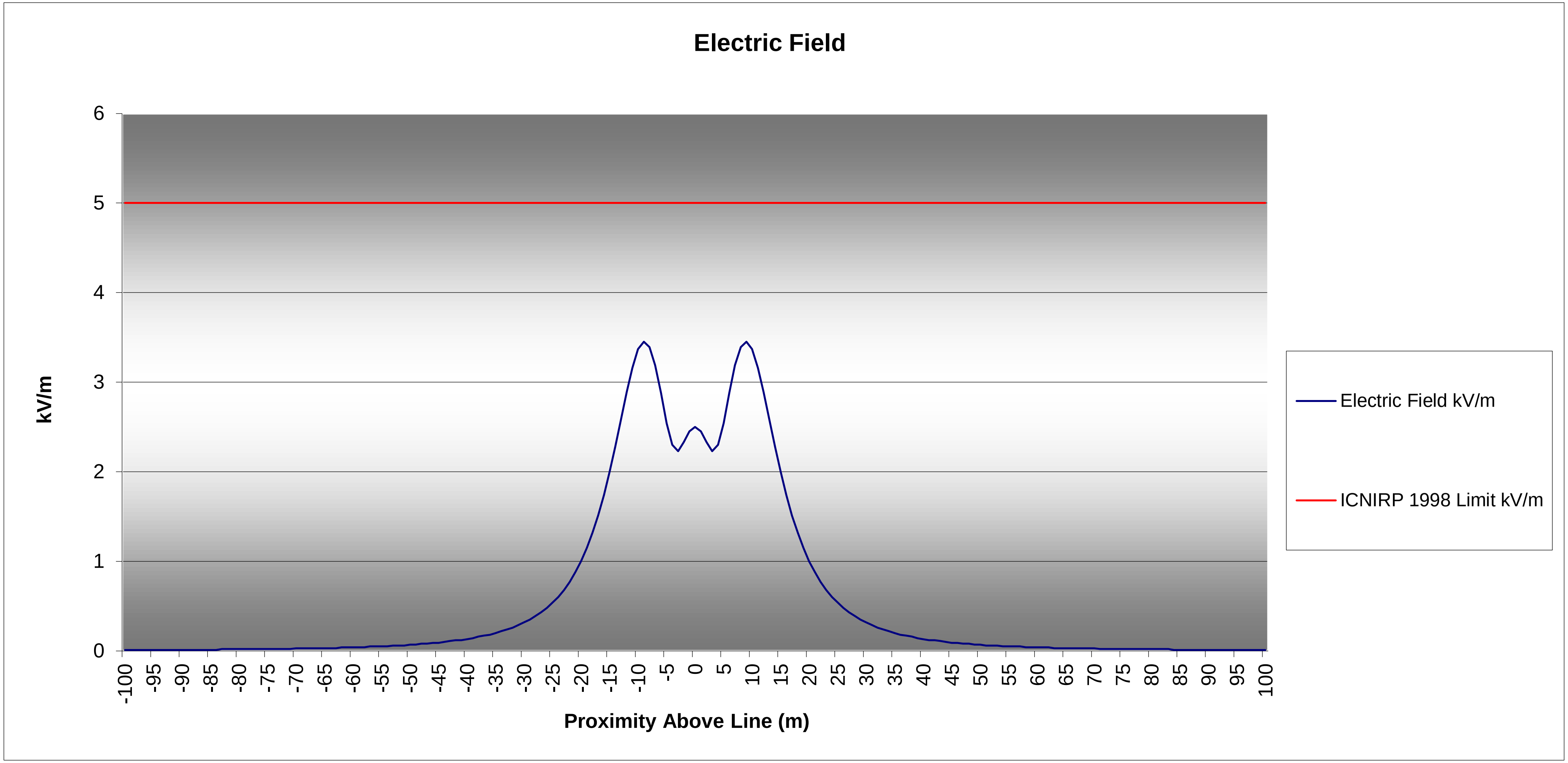

Plate 4: Maximum Possible Electric Field from the 220 kV OHL Cables (modelled at 376 MW)

A-12.3.7.3 Worst Case EMF emissions from the potential Castlewaller Windfarm grid connection (underground cable)

<u>Worst Case Magnetic Fields - Potential Castlewaller Windfarm Grid Connection (underground cable):</u>

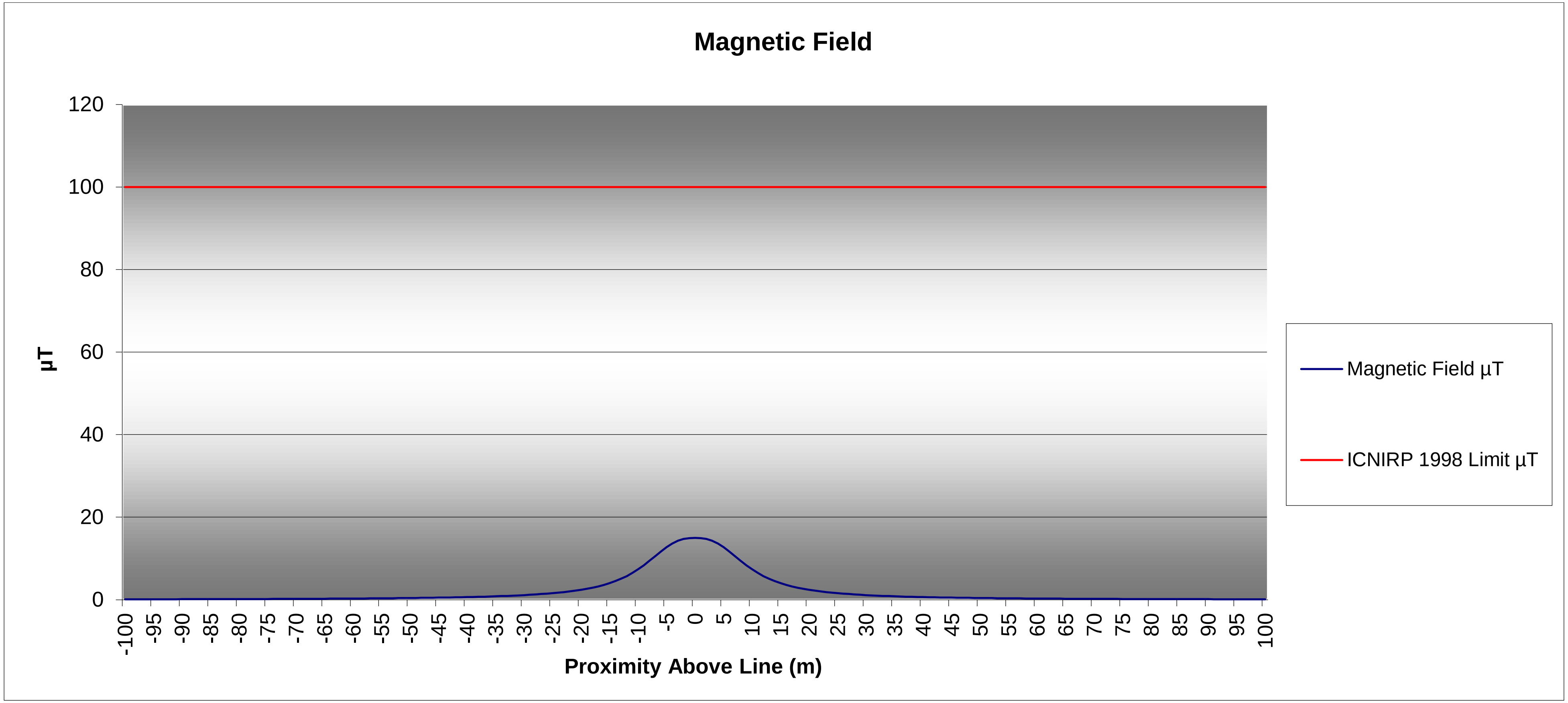

Plate 5: Maximum Possible Magnetic Field from the 110 kV Underground Cables (modelled at 40MW)

Worst Case Electric Fields - Potential Castlewaller Windfarm Grid Connection (underground cable):

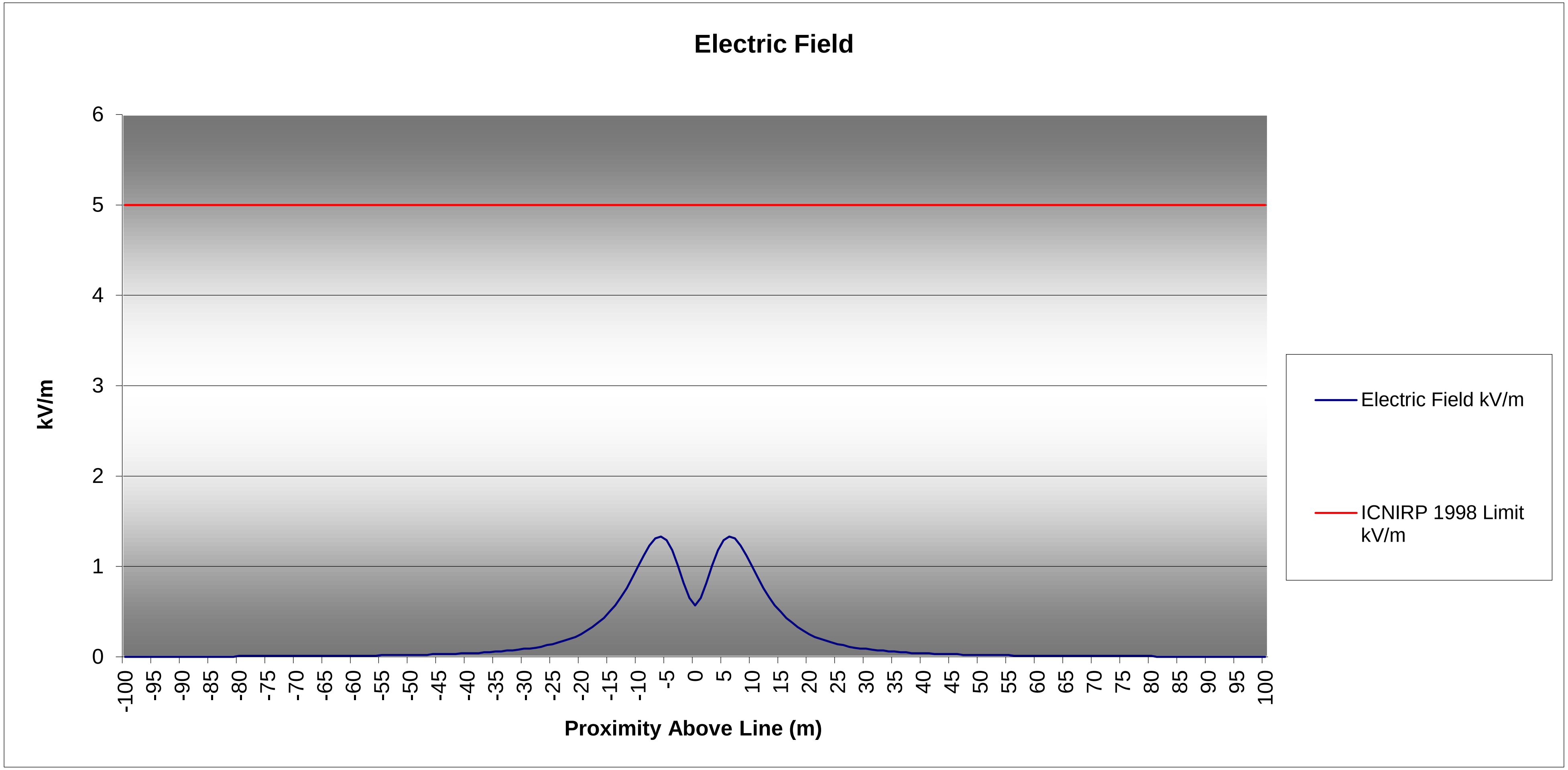

Plate 6: Maximum Possible Electric Field the 110 kV Underground Cables (modelled at 40MW)