Appendix L

Electric and Magnetic Fields Report

PROJECT BOOST

Penrith HV BESS – Electric and Magnetic Fields Report

AUSCONNEX

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aurecon

Bringing ideas to life

Executive summary

Ausconnex aims to develop a grid-scale High Voltage (HV) Battery Energy Storage System (BESS) with a capacity of up to 100 megawatts (MW) and 200 megawatt hours (MWh) in Penrith in Western Sydney, New South Wales. Aurecon has been engaged to undertake an electric and magnetic fields (EMF) assessment for the project.

The scope of Aurecon's assessment relating to the project encompasses the following:

- Provision of a brief description of EMF in relation to human health.
- Calculation of the electric and magnetic field contribution of the proposed cable feeder at one metre above ground level, 20.
- An assessment of the compliance of the anticipated field levels with the relevant national and international EMF guidelines.
- An assessment of compliance of the proposed underground feeder with precautionary and prudent avoidance principles in accordance with the relevant guidelines.
- Preparation of a report covering the EMF assessment to inform the overall environment assessment.

Electric and magnetic field assessment findings

Aurecon has modelled the EMF levels of the proposed 33kV feeder against the International Commission on Non-Ionizing Radiation Protection (ICNIRP) public exposure guidelines as recommended by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Based on the modelling results we have arrived at the following conclusions.

- The contribution of the proposed underground feeder to the magnetic field environment is predicted to be well within the ICNIRP Guideline Reference Level of 2,000mG.
- Being of underground cable construction, the electric fields associated with the cable will be contained within them and, accordingly, the proposed feeder will not produce external electric fields.

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Term	Description
AC	air conditioner
AIMDs	Active implanted medical devices
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
BESS	Battery energy storage system
CNS	Central nervous system
DC	Direct current
ELF	Extremely low frequency
EMF	Electric and magnetic fields
EMR	Electromagnetic radiation
ENA	Energy Network Australia
HV	High voltage
HVAC	High voltage alternating current
ICNIRP	International Commission on Non-Ionizing Radiation Protection
kV	Kilovolts
mG	Milligauss
MW	Megawatts
MWh	Megawatt hours
NRPB	National Radiological Protection Board's
O&M	Operation and maintenance
OEM	Original Equipment Manufacturers
RMUs	Ring Main Units
SEARs	Secretary's Environmental Assessment Requirements

1 Introduction

1.1 Project background

The Penrith High Voltage (HV) Battery Energy Storage System (BESS) project involves the development, construction, operation and decommissioning of a grid-scale HV BESS with a capacity to supply up to 100 megawatts (MW) of power and the ability to store up to 200 megawatt-hours (MWh) of energy adjacent to the existing Penrith Substation to meet the growing demands of the local Penrith community.

The Penrith HV BESS project includes the following key components:

- Electrical infrastructure including:
  - a 100MW/200MWh BESS comprised of 48 battery containers installed in enclosures (thermal cabinet) and associated ancillary infrastructure. Lithium-ion phosphate is the preferred Lithium-ion battery chemistry for reasons of safety and widespread availability from BESS Original Equipment Manufacturers (OEM). The battery container includes an integrated air conditioner (AC) power inverter;
  - step up transformers, auxiliary transformer and ring main units (RMUs)
  - 33 kilovolt (kV) switch room and control room;
  - installation of one (1) x 33kV underground feeder and entry point for HV BESS cabling to connect the Project to the Penrith Substation via new and existing conduits; and
  - two harmonic filters.
- Other permanent ancillary infrastructure including:
  - earth grading and levelling works to allow for installation of concrete pads for the HV BESS containers and associated infrastructure;
  - Operation and Maintenance (O&M) building;
  - car parking;
  - security fencing, lighting, signage and lightning protection;
  - fire detection and suppression equipment;
  - internal access road (about 6 metres (m) wide) and driveway access off Thornton Drive;
  - formalised underground stormwater network, and provision for water detention (for water quality and fire water purposes);
  - vegetation clearance of non-native vegetation; and
  - noise attenuation walls (7m high).
- Temporary construction facilities including:
  - site office;
  - construction compounds and laydown areas; and
  - stormwater and sediment controls for the project site.

The overall indicative project footprint is about 0.9 hectares. This includes the temporary construction facilities as well as the 33kV grid connection. Typically, BESS containers are 2.8m in height, with a total associated footprint of 50 square metres in area per container. There are 48 battery containers proposed. The BESS containers typically contain internal heating, ventilation and cooling (HVAC) controls. The step-up transformer tank would be up to about 2.5m high.

Figure 1-1 shows the concept design for the Penrith HV BESS project. The final Penrith HV BESS project configuration would be confirmed pending detailed design.

1.2 Key components

The Penrith HV BESS project involves the following key components:

- electrical infrastructure including:
  - a 100MW/200MWh HV BESS comprised of 48 battery containers installed in enclosures (thermal cabinet) and associated ancillary infrastructure. Lithium-ion is the preferred battery chemistry for the project for reasons of safety and widespread availability from BESS OEM) The battery container includes an integrated AC power inverter;
  - step up transformers, auxiliary transformer and RMUs;
  - 33 kilovolt (kV) switch room and control room;
  - installation of one (1) x 33kV underground cable and entry point for HV BESS cabling to connect the Project to the existing Penrith Substation via new and existing conduits; and
  - two harmonic filters.
- other permanent ancillary infrastructure; and
- temporary construction facilities.

1.3 Purpose and scope of this report

The main purpose of this report is to assess the potential electric and magnetic field (EMF) impacts from construction and operation of the Penrith HV BESS project to support the environmental assessment of the Project in accordance with Part 4 of the *Environmental Planning and Assessment Act 1979*. Electric and magnetic fields associated with the new infrastructure are only present once the infrastructure is commissioned and energised and accordingly the focus of this report is on the operational field levels.

The scope of Aurecon's assessment encompasses the following:

- Provision of brief description of EMF in relation to human health.
- Calculation of the magnetic field associated with the proposed underground feeder one metre above ground level, extending up to 20m on each side of the centreline.
- An assessment of the compliance of the anticipated field contributions with the relevant national and international EMF guidelines.
- An assessment of the compliance of the proposed feeder with precautionary and prudent avoidance principles in accordance with the relevant guidelines.
- An assessment of the EMF from the proposed BESS.

Potential cumulative impacts associated with the existing electrical infrastructure are not included in the scope of this assessment.

Figure 1-1: Site layout

1.4 Secretary's Environmental Assessment Requirements

The report has been prepared in accordance with the Planning Secretary's Environmental Assessment Requirements (SEARs) SSD-78368474 for the Project as well as relevant government assessment requirements, guidelines and policies. The requirements specific to this assessment and where these aspects are addressed in this technical report are outlined in Table 1-1.

Table 1-1: Secretary's Environmental Assessment Requirements

Key issues	SEARs to be addressed by the study	Where addressed in this report
Hazards – Health	Health - an assessment of potential hazards and risks including but not limited to fires, spontaneous ignition, electromagnetic fields or the proposed grid connection infrastructure against the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines for limiting exposure to Time-varying Electric, Magnetic and Electromagnetic Fields;	Chapters 4 and 5 provide a desktop assessment of the potential hazards and risks associated with EMF during the operation of the Project.

2 Overview of electric and magnetic fields

2.1 General description

Whenever electrical equipment is in service, it produces an electric field and a magnetic field. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires. Being related to voltage, the electric fields associated with high voltage equipment remain relatively constant over time, except where the operating voltage changes. Conversely, being related to current, the magnetic field strength resulting from an electrical installation varies continually with time as the load on the equipment varies.

EMF in the low frequency range of the electromagnetic spectrum fall between the 1 Hertz (Hz) to 100kHz range. EMF that is classified as extremely low frequency (ELF) by Energy Network Australia (ENA) is associated with the generation, distribution, and use of electricity power systems that have a frequency of 50Hz.

EMFs at 0Hz frequency are classified as static fields and are associated with generation, distribution and use of electricity power system that operate at 0Hz frequency such as battery systems, traction power, etc.

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and as such can exist independently.

Further detail on EMFs can be found in Appendix A.

2.2 Electric and magnetic fields and health

It is known that EMFs at magnitudes much higher than those encountered in everyday life can interact with the central nervous system. In addition, the possibility of adverse health effects due to the much lower EMFs associated with electrical equipment has been the subject of extensive research throughout the world for more than 40 years.

To date, adverse health effects due to fields of the levels normally associated with electrical infrastructure, have not been established. However, due to a body of epidemiological evidence, the possibility that such effects may exist has not been ruled out.

2.2.1 Summary of health effects

While EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Nevertheless, high electric field strengths, such as those associated with the highest voltage transmission lines or high voltage equipment in major substations, can approach a level at which “nuisance shocks” can occur and this phenomenon needs to be managed. This can be done via appropriate easement and fencing practices.

Magnetic fields are not readily shielded, are more ubiquitous and remain the subject of some debate. Accordingly, much of the health research has been directed towards magnetic fields.

When exposed to direct current (DC) magnetic fields higher than 2-3 Tesla, humans are exposed to transient sensations such as vertigo and nausea. These effects are not adverse health effects in themselves but may be annoying and may impair normal functioning. There is no evidence for adverse effects of exposure to fields up to 8 Tesla. Static electric field do not penetrate the human body and induces a surface with electric charge. Sufficiently large electric charge may be perceived through its interaction with body hair and other phenomena and cause microshocks.

A large number of studies have been conducted over many years to investigate the possibility of adverse health consequences from extremely low frequency electric and magnetic fields. These studies have addressed a wide range of end points including childhood leukaemia, other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioral effects and neurodegenerative disease. The most recent scientific reviews by authoritative bodies are reassuring for most potential health end points. However, statistical associations between prolonged exposure to elevated magnetic fields and childhood leukaemia have persisted. This led the International Agency for Research on Cancer (Ref. B-1) in 2002 to classify magnetic fields as a "possible carcinogen", a categorisation used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals.

The fact that, despite over 30 years of laboratory research, no mechanism for an effect has been established, lends weight to the possibility that the observed statistical associations reflect some factor other than a causal relationship. This point is made in the 2001 report of the UK National Radiological Protection Board's (NRPB) Advisory Group, chaired by eminent epidemiologist, the late Sir Richard Doll (Ref. B-2)

> *"in the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children." (page 164)*

Further discussion of the above including footnotes can be found in Appendix B.

2.3 Health guidelines

An assessment of the potential hazards and risks associated with EMF due to the Project considered the International Commission on Non-Ionizing Radiation Protection (ICNIRP) *Guidelines for Limiting Exposure to Time-varying Electric, Magnetic and Electromagnetic Fields* (the Guidelines). ICNIRP has published separate guidelines for static fields (0Hz) and low frequency (1Hz to 100kHz) fields. The ICNIRP Guidelines are considered by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and the broader scientific community as international best practice for the protection of humans exposed to EMF.

The Guidelines are applicable to both occupational and public exposure with separate guidance given for either occupational or general public exposures. Occupationally exposed individuals are those who are exposed under controlled conditions associated with their occupational duties, trained to be aware of potential radiofrequency EMF risks and to employ appropriate harm-mitigation measures. The general public are individuals of all ages and of differing health statuses, which includes more vulnerable groups or individuals, and who may have no knowledge of or control over their exposure to EMFs. These differences suggest the need to include more stringent restrictions for the general public would not be suitably trained to mitigate harm or may not have the capacity to do so (ICNIRP, 2010).

2.3.1 50Hz fields' exposure guideline

Since late 2015, the ARPANSA[1], has adopted the *Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz))* published by the ICNIRP in 2010. In adopting the ICNIRP Guidelines ARPANSA noted:

> *"The ICNIRP ELF guidelines are consistent with ARPANSA's understanding of the scientific basis for the protection of the general public (including the foetus) and workers from exposure to ELF EMF." (Ref. C-2)*

The ICNIRP Guideline sets 'Basic Restrictions', which are derived from the levels at which interactions with the central nervous system (CNS) are established, with a safety factor applied. The Basic Restrictions are expressed in terms of electric field levels within the human body but, as these levels can only be assessed by sophisticated computer modelling of the body, ICNIRP also sets 'Reference Levels', expressed in terms of kV/m and microtesla[2] for electric and magnetic fields respectively. These levels are conservatively set such that, provided they are met, the Basic Restrictions would also be met without the need for more comprehensive analysis. The ICNIRP 'Basic Restrictions' and 'Reference Levels' for the general public are reproduced in Table 2-1. As noted above, these criteria apply to both adults and children and are independent of duration of exposure.

Table 2-1: ICNIRP Guideline levels

Parameter	Basic restriction (volts per metre)	Reference level
Electric Field – General Public	CNS tissue of the head: 0.02 All tissue of head and body: 0.4	5,000 Volts per metre (V/m)
Magnetic Field - General Public	CNS tissue of the head: 0.02 All tissue of head and body: 0.4	2,000 milligauss (mG)

In applying the ICNIRP Guideline, it is important to recognise that the numerical limits, e.g. 2,000mG, are based on established health effects. In ICNIRP's fact sheet on the guidelines (Ref. C-3), it notes that:

> *"It is the view of ICNIRP that the currently existing scientific 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 for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well-established adverse effects and serve as the basis for guidance."*

Being based on established biological effects (which occur at field levels much higher than those normally encountered in the vicinity of electrical equipment), the (numerical) exposure limits in the guidelines and standards cannot be said to define safe limits for possible health effects, should these exist, from magnetic fields at levels normally encountered in the vicinity of electrical equipment.

The principal compliance criteria for AC fields used for this assignment are as per Table 2-1.

2.3.2 DC fields exposure guideline

Guidelines on Limits of Exposure to Static Magnetic Fields (0Hz) published by ICNIRP for static magnetic fields have been used as the DC assessment criteria for the purpose of this assessment. The ICNIRP 'Reference Levels' for static (0Hz) magnetic fields are reproduced in Table 2-2.

Table 2-2: Static or DC magnetic field exposure limit

Exposure type	Exposure part	Reference level
Magnetic Field – Occupational	**Head and trunk**	**2,000,000µT**
	Limbs	**8,000,000µT**
Magnetic Field – General Public	**Any part of body**	**400,000µT**

In relation to the static electric fields, no specific exposure limit is recommended by the ICNIRP, as they only interact at the surface of the body.

2.4 Prudent avoidance

Given the inconclusive nature of the science regarding EMF at levels commonly associated with electrical equipment and human health, it is widely considered that a prudent approach is the most appropriate response under the circumstances. Prudent avoidance is a precautionary concept developed to address the possibility of health effects from prolonged exposure to field levels much lower than those for which effects have been established.

Under this approach, subject to modest cost and reasonable practicality, the owners of electric power infrastructure should design their facilities to reduce the intensity of the fields they generate in frequented areas where prolonged[3] exposure is possible.

Further general discussion on this subject can be found in Appendix D and the implications for this assessment are discussed in Section 4.2.2.

2.5 Medical implants

In addition to direct interactions with the human body, EMFs also have the potential to interfere with active implanted medical devices (AIMDs) such as cardiac pacemakers, insulin pumps etc. A wide variety of devices are used in modern medicine and, due to the multiplicity of EMF sources in the modern environment, they are generally subject to standards regarding immunity from interference.

In Europe, the relevant European Directive (90/385/EEC) requires designers and manufacturers of AIMDs to make them immune to interference in "reasonably foreseeable" circumstances. The relevant European Standard (CENELEC 50527-1) interprets this as meaning that devices should be immune from interference up to the ICNIRP general public reference levels. Similar requirements apply in the UK. However, as the magnetic field reference level at the time of the European directive was 1,000 mG, rather than the present 2,000mG, it is customary (and conservative) to assume that AIMDs should be immune to interference from magnetic fields only up to 1,000 mG.

The relevant Australian Standard (AS 45502-1: 2002), which was reproduced from a European Standard (EN 45502-1: 1997), stipulates that AIMDs be immune from risks connected with reasonably foreseeable environmental conditions such as magnetic fields, external electrical influences etc. In that context, as a first guide, the Australian Standard cites a magnetic intensity of 150 Amps/metre[4] (1,885mG).

Accordingly, as the highest magnetic fields associated with 33kV cable are of the order of a ‘hundred mG’, from a practical perspective, AIMDs which comply with the relevant Standards should be immune from transmission line interference. Nevertheless, concerned wearers of AIMDs should consult their treating physician for further information or advice, based on the specific characteristics of their actual device.

3 Input information and aspects of field predictions

The project would comprise of the BESS (battery system units, HV and MV connections for the battery system) and underground feeder connecting to the existing Penrith Transmission Substation.

This section will cover the input data, approach and assumptions made to assess magnetic field contributions associated with the underground 33kV feeder and BESS.

3.1 Input information for underground feeder

An in-house excel tool was used calculate the magnetic field contributions associated with the underground 33kV feeder The input data listed below, required for the calculations on which this assessment is as follow.

- cable details including size and layout;
- peak cable loading information for 33kV operation;
- cable route and distance from frequented areas; and
- proposed Penrith HV BESS project layout.

The cable arrangement is shown in the cross sections in Figure 3-1.

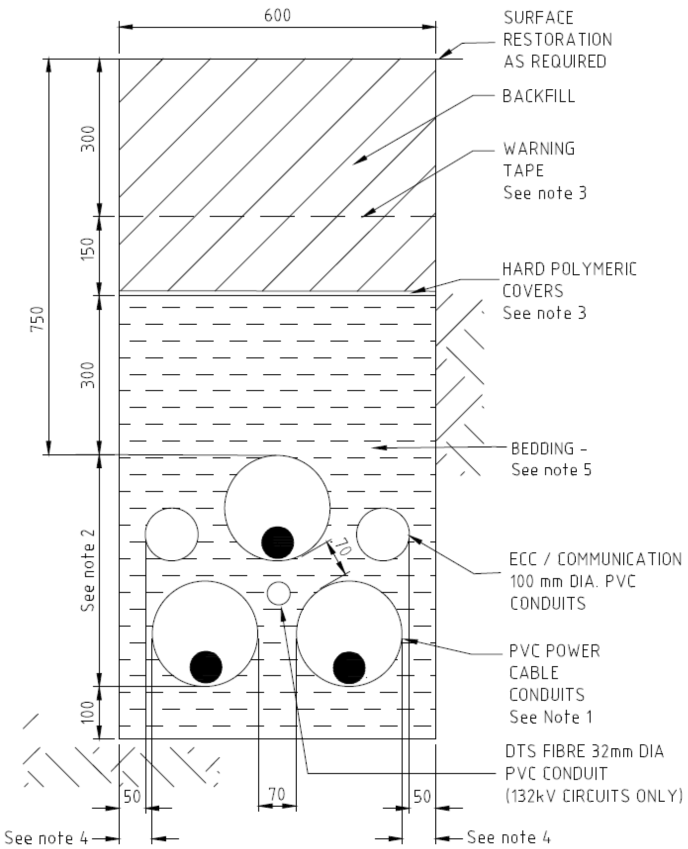

Figure 3-1: Cable arrangement for 33kV feeder

3.2 Data and assumptions for the assessment

The following assumptions have been made in undertaking the EMF modelling:

- The loading in the proposed feeder for grid connection has been taken as the system normal peak value.
- A qualitative assessment has been performed for magnetic field contributions associated with the BESS.

3.3 Approach

As noted in Appendix A – General Description of Electric and Magnetic Fields, while EMFs involve both electric and magnetic components. Electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields.

3.3.1 Underground feeder

The electric field associated with low-voltage cables (33kV in this instance) is generally considered negligible, as electric fields are expected to be contained or shielded by the cable sheath. Additionally, the backfill material above the cable acts as a conductive medium, helping to dissipate the electric field to some extent. Accordingly, the remainder of the underground feeder assessment is focused on the magnetic field.

The magnetic fields associated with the proposed 33kV feeder is influenced by their physical arrangements. Based on the available design and loading information, the magnetic field contribution of the feeder has been modelled using established in-house software, which has been extensively validated against other comparable software. Fields have been modelled at a height of one metre above ground level in accordance with international standards.

The results obtained from the magnetic field modelling of the proposed 33kV underground feeder is shown in the following sections. The magnetic field contributions are presented as a profile indicating the magnetic field contribution perpendicular to the proposed feeder.

3.3.2 Battery energy storage system

The following approach has been adopted in the assessment of the HV battery system:

- Examine and describe relevant aspects of the existing environment.
- Review and describe the security fencing associated with the site.
- Examine the major BESS elements and describe likely magnetic fields at relevant locations across the site, including those areas potentially accessible to the general public.
- Summarise findings in relation to the relevant EMF guidelines.

4 Potential EMF impacts and field characterisation

4.1 Underground feeder

This section provides the predicted magnetic field calculation for the proposed underground 33kV feeder.

4.1.1 Magnetic field

The predicted magnetic fields contributions of the proposed underground feeder under system normal peak conditions for 33kV operation are shown in Figure 4-1

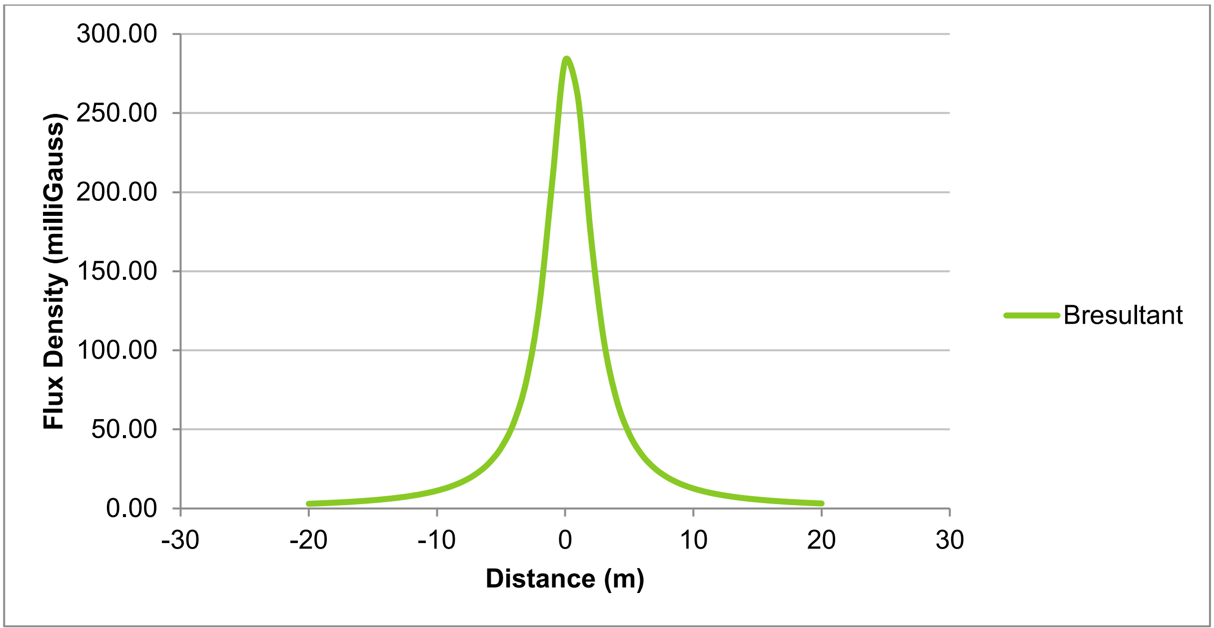

Figure 4-1: Predicted magnetic field profile for 33kV underground feeder

As depicted in Figure 4-1, under system normal average loading conditions, the predicted magnetic field contribution directly above the cable trench is 283.3mG for 33kV, which is about 14.2% of the ICNIRP Guideline Reference Level of 2,000mG.

The nearest frequented area to the project boundary is 20m away. Consequently, the resultant magnetic field level approximately 20m from the centre of the feeder is around 3mG, which is about 0.15% of the ICNIRP guideline level.

4.1.2 Magnetic fields experienced in everyday life

In considering the fact that the magnetic fields associated with the proposed transmission lines are quite localised and, due to their location inside the BESS yard where no public members will be able to access, are unlikely to be experienced by people, other than intermittently, it is useful to recognise that life in the modern world involves moving from one source of magnetic fields to another. To put this into perspective, the Energy Networks Association has published a series of typical magnetic field levels associated with particular appliances and infrastructure at normal user distance[8]. These are set out in Table 4-1.

Table 4-1: Typical ELF magnetic field levels associated with appliances and infrastructure

Appliance	Typical measurement (mG)	Typical range of measurements (mG)[9]
Electric stove	6	2 – 30
Refrigerator	2	2 – 5
Electric kettle	3	2 – 10
Toaster	3	2 – 10
Electric blanket	20	5 – 30
Hair dryer	25	10 – 70
Pedestal fan	1	0.2 – 2
Substation ▪ Substation fence	 5	 1 – 8
Distribution line ▪ Under line ▪ 10 m away	 10 -	 2 – 30 0.5 – 10
Transmission line ▪ Under line ▪ Edge of easement	 20 10	 10 – 200 2 – 50

It is noted that the levels in Table 4-1 are typical only and fields may vary from the ranges shown.

The magnetic field contribution of the proposed feeder at the nearest frequented area are well within the range of those normally encountered in everyday life. It is noted that the levels are typical only and fields may vary from the ranges shown. Although Table 4-1 does not cover underground distribution feeders, it is important to note that, due to their proximity to the ground compared to overhead lines, the electric fields at one metre above ground are higher for underground feeders. However, these fields decrease rapidly and, within just a few metres, are lower than those of an equivalent overhead line. The predicted fields for the proposed 33kV underground feeder are typical in this context.

4.2 Battery energy storage system

4.2.1 Battery energy storage system elements

In addition to the underground cable connecting to the adjacent existing Penrith Substation, the Penrith HV BESS project would introduce the following new infrastructure that would contribute to the EMF environment:

- a 100MW/200MWh HV BESS comprised of 48 battery containers installed in enclosures (thermal cabinet) and associated ancillary infrastructure. Lithium-ion is the preferred battery chemistry for the project for reasons of safety and widespread availability from BESS OEM. The battery container includes an integrated AC power inverter;
- step up transformers, auxiliary transformers and RMUs;
- 33kV switch room and control room; and
- two harmonic filters.

4.2.2 Magnetic field

The indicative development footprint is proposed to be located adjoining within the fenced Penrith Substation. The Site for the 100MW/200MWh HV BESS is in a highly urbanised, industrial and residential area. The nearby areas which could be frequented by the public include the following:

- industrial land adjoining the eastern boundary (Productivity Bootcamp and Museum of Fire located 20m east);
- commercial businesses located approximately 50m north of the Site;
- medium and high-density residential buildings situated along Combewood Avenue, Penrith, located around 200m east of the project site and separate from the site by Bootcamp and Musuem of Fire of intervening industrial parcels of land;
- commercial businesses servicing industrial zone located approximately 50m north of the Site;
- dairy distribution centre located approximately 35m south of the Site;
- industrial land to the west of the Site.

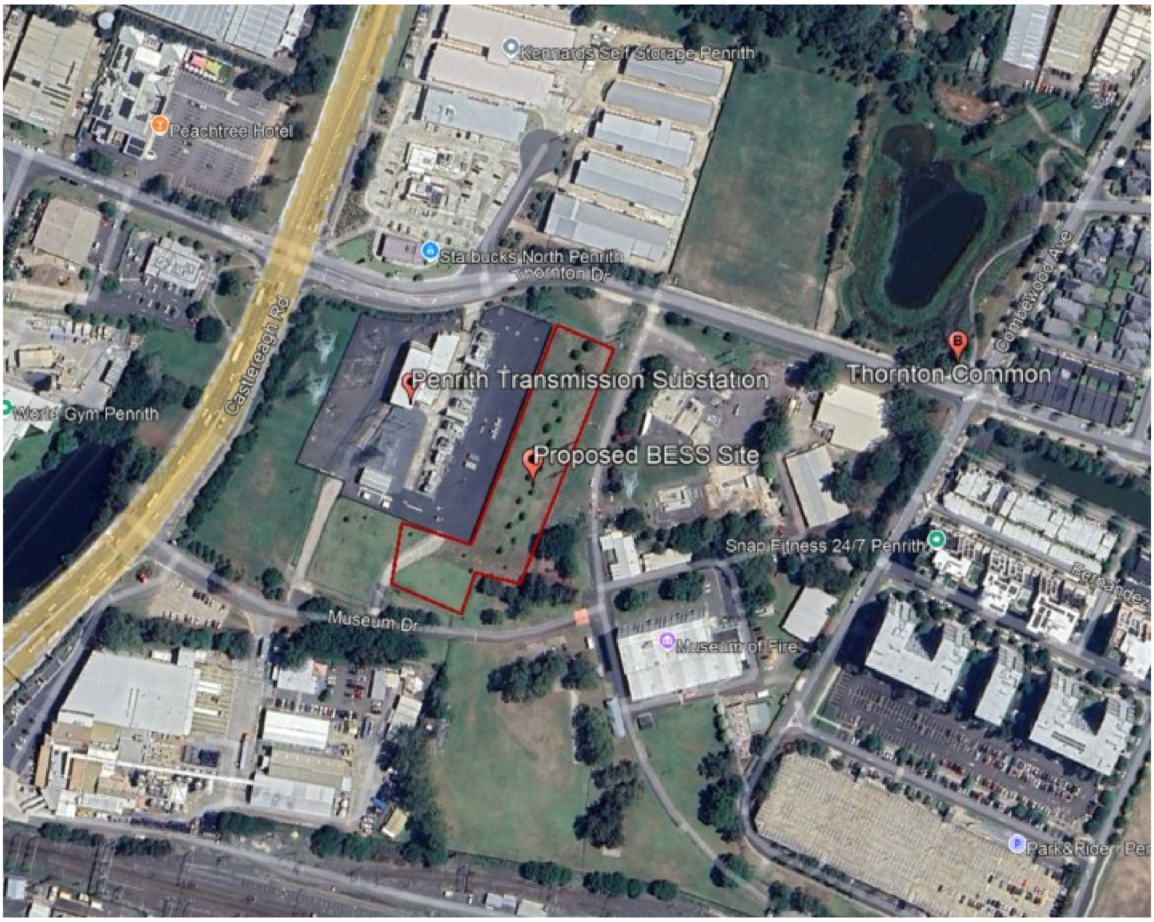

Figure 4-2: Surrounding area of the project site

The HV BESS project will be installed within the curtilage of the existing fenced Penrith transmission substation site. Access to the entire project site will thus be restricted to authorised persons only by high-security fence around the perimeter of the BESS yard restricting public access,

The battery unit itself produces DC magnetic fields that may vary depending on its configuration, capacity, and housing design. The battery unit are to be designed by the manufacturer ensuring that these DC fields are localized within the battery unit and remain within the ICNIRP guideline levels. Consequently, the typical field levels outside the battery unit, in areas accessible to the public, are expected to be negligible.

The highest AC magnetic fields within a BESS compound are typically found near the inverters and transformers. These fields are influenced by the 33kV connection between these equipment and are expected to be similar to, or lower than, the fields associated with underground cable, as described in Section 4.1.1. The BESS yard is remotely operated with operational maintenance visits only expected annually (as per manufacturer requirements).

Given the above, and the nearest frequented area to this site i.e. industrial business on eastern boundary located approximately 20m away, the contribution of the proposed battery system to the field levels at the nearest frequented area is expected to be negligible.

5 Compliance with EMF guidelines and prudence avoidance principles

5.1 Compliance with health guidelines

5.1.1 Magnetic field

The contribution of the proposed underground feeder to the magnetic field environment is predicted to be well within the ICNIRP Guideline Reference Level of 2,000mG. Relevant magnetic field values are summarised in Table 5-1.

Table 5-1: Summary of magnetic field results

Feeder voltage	Directly under the transmission line	
33kV	(mG)	% of ICNIRP Guideline Ref. Level
	283.3	14.2

5.1.2 Electric field

As noted previously, being underground cable construction, the proposed cable will not produce external electric fields.

5.2 Assessment against prudence avoidance principles

It is widely accepted that a prudent/precautionary approach continues to be the most appropriate response to health concerns regarding EMF as outlined in Appendix D in the Australian context, ENA's position, as adopted in their EMF Management Handbook (Ref D.5), states:

"Prudent avoidance does not mean there is an established risk that needs to be avoided. It means that if there is uncertainty, then there are certain types of avoidance (no cost / very low-cost measures) that could be prudent."

The World Health Organization notion of prudence or precaution state:

"Provided that the health, social and economic benefits of electric power are not compromised, implementing very low-cost precautionary procedures to reduce exposure is reasonable and warranted."

Under this approach, the electricity infrastructure has been designed and located to install the cable within the existing fenced off substation to be as far as practicable from dwellings, surrounding businesses, and industrial uses as per ENA policy of prudent avoidance.

The HV BESS project seeks to contain and minimise the potential for EMF consistent with the principles of prudent avoidance.

Appendices

Appendix A
General description of electric and magnetic fields

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and can exist independently. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires.

An **electric field** is a region where electric charges experience an invisible force. The strength of this force is related to the voltage, or pressure, which forces electricity along wires. Electric fields are strongest closest to their source, and their strength diminishes rapidly with distance from the source, in much the same way as the warmth of a fire decreases with distance. Many common materials – such as brickwork or metal – block electric fields, so they are readily shielded and, for all practical purposes, do not penetrate buildings. They are also shielded by human skin, such that the electric field inside a human body will be at least 100,000 times less than the external field (Ref A-1). Being related to voltage, the electric fields associated with high voltage aerial lines and electrical substations remain relatively constant over time, except where the operating voltage changes.

A **magnetic field** is a region where magnetic materials experience an invisible force produced by the flow of electricity (known as electric current and measured in Amperes). The strength of a magnetic field depends on the size of the current and decreases as distance from the source increases. The magnetic field strength resulting from an electrical installation varies continually with time and is affected by a number of factors including:

- total electric load;
- size and nature of the equipment;
- design of the equipment; and
- layout and electrical configuration of the equipment and its interaction with other equipment.

While electric fields are blocked by common materials, this is not the case with magnetic fields. This is why locating equipment in enclosures or underground will eliminate any external electric field but not the magnetic field.

Alternating electric and magnetic fields are produced by any electric wiring or equipment carrying alternating current (AC). This current does not flow steadily in one direction but oscillates backwards and forwards at a frequency[11] of 50Hz and hence the fields produced by AC systems oscillate at the same frequency. This frequency falls into a range referred to as ELF, so the electric and magnetic fields are referred to as ELF fields.

Electromagnetic radiation

It is not uncommon for the ELF EMF associated with electrical equipment to be confused with electromagnetic radiation (EMR). The fact that, in many jurisdictions, agencies which regulate the various forms of EMR are also involved in the setting of guidelines/standards for EMF tends to add to this confusion.

Electromagnetic radiation is a term we use to describe the movement of electromagnetic energy through the propagation of a wave. This wave, which moves at the speed of light in a vacuum, is composed of electric and magnetic waves which oscillate (vibrate) in phase with, and perpendicular to, each other. This is in contrast to EMF, where the electric and magnetic components are essentially independent of one another.

Electromagnetic radiation is classified into several types according to the frequency of its wave; these types include (in order of increasing frequency): radio waves, microwaves, terahertz radiation, infra-red radiation, visible light[12], ultraviolet radiation, x-rays and gamma rays. Whereas EMR causes energy to be radiated outwards from its source e.g. light from the sun or radio-frequency signals from a television transmitter, EMFs cause energy to be transferred along electric wires.

In the context of EMF and health, the distinction between EMF and EMR is addressed by the New Zealand Ministry of Health in its public information booklet “Electric and Magnetic Fields and Your Health” (Ref A-2) as follows:

> *“The electric and magnetic fields around power lines and electrical appliances are not a form of radiation. The word “radiation” is a very broad term but generally refers to the propagation of energy away from some source. For example, light is a form of radiation, emitted by the sun and light bulbs. ELF fields do not travel away from their source but are fixed in place around it. They do not propagate energy away from their source. They bear no relationship, in their physical nature or effects on the body, to true forms of radiation such as x-rays or microwaves.”*

References

A-1. World Health Organization: *Environmental Health Criteria Vol. 238*: Extremely low frequency fields. (2007).

A-2. New Zealand Ministry of Health: *Electric and Magnetic Fields and Your Health*. (2008).

Appendix B
Overview of EMF and health

Research into EMFs and health is a complex area involving many scientific disciplines – from biology, physics and chemistry to medicine, biophysics and epidemiology. Many of the health end points of interest to researchers are quite rare. In this context, it is well accepted by scientists that no study considered in isolation will provide a meaningful answer to the question of whether or not EMFs can contribute to adverse health effects. In order to make an informed conclusion from all of the research, it is necessary to consider the science in its totality. Over the years, governments and regulatory agencies around the world have commissioned independent scientific review panels to provide such overall assessments.

Extremely low frequency fields

The possibility of adverse health effects due to the ELF EMFs at levels commonly associated with electrical equipment has been the subject of extensive research throughout the world. To date, while adverse health effects have not been established, the possibility that they may exist cannot be ruled out.

While EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Nevertheless, high electric field strengths, such as those associated with the highest voltage transmission lines or high voltage equipment in major substations, can approach a level at which "nuisance shocks" can occur and this phenomenon needs to be managed.

Magnetic fields are not readily shielded, are more ubiquitous and remain the subject of some debate. Accordingly, much of the remainder of this section is directed towards magnetic fields.

The most recent scientific reviews by authoritative bodies are reassuring for most potential health end points. However, statistical associations[13] between prolonged exposure to elevated magnetic fields and childhood leukaemia have persisted. This led the International Agency for Research on Cancer (Ref. B-1) in 2002 to classify magnetic fields as a "possible carcinogen"[14].

The fact that, despite over 30 years of laboratory research, no mechanism for an effect has been established, lends weight to the possibility that the observed statistical associations reflect some factor other than a causal relationship. This point is made in the 2001 report of the UK National Radiological Protection Board's (NRPB) Advisory Group, chaired by eminent epidemiologist, the late Sir Richard Doll (Ref. B-2).

> *"In the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children." (page 164)*

Corona ions

Although not strictly ELF fields per se, the phenomenon known as corona ions has been raised in some quarters as an alternative explanation for possible health effects attributed to EMF.

When high voltage conductors are surrounded by air, they can cause some of the air molecules to become electrically charged. In the mid to late 1990s, it was hypothesised by a group at Bristol University that these charged molecules can attach to pollutant particles, which may also be present in the air. It was further hypothesised that, especially downwind of high voltage power lines, the charged pollutant particles are more likely to be deposited on the skin or in the lungs, thereby increasing the risk of pollution related health effects.

In considering this issue, it is important to note that it is customary to design transmission lines to limit the conductor surface gradients under normal weather conditions to prevent the inception of corona.

The hypothesis has been examined by various independent health authorities over the years as discussed below.

World Health Organization

The World Health Organization addressed the corona ion hypothesis in its 2007 monograph on extremely low frequency fields (Ref B3) as follows:

> "*High-voltage power lines produce clouds of electrically charged ions as a consequence of corona discharge. It is suggested that they could increase the deposition of airborne pollutants on the skin and on airways inside the body, possibly adversely affecting health. However, it seems unlikely that corona ions will have more than a small effect, if any, on long term health risks, even in the individuals who are most exposed.*"

National Radiological Protection Board

In 2004, after having reviewed the issue, the NRPB's Ad Hoc Group on Corona Ions released a report "Particle deposition in the vicinity of power lines and possible effects on health" (Ref B-4). The report concluded that:

> "*The effects of external fields on deposition of particles in the respiratory tract, if any, are likely to be very small*";

> "*Any health risks from the deposition of environmental particulate air pollutants on the skin appear to be negligible*."

and

> "*…it seems unlikely that corona ions would have more than a small effect on the long-term health risks associated with particulate air pollutants, even in the individuals who are most affected. In public health terms, the proportionate impact will be even lower because only a small fraction of the general population lives or work close to sources of corona ions*."

Appendix C
Health guidelines

Health guidelines for extremely low frequency electric and magnetic fields

The World Health Organization recognises two international EMF/health guidelines:

- the Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz) produced by the International Commission on Non-Ionising Radiation Protection (ICNIRP) Ref C-1); and
- the IEEE Standard C95.1, produced by the International Committee on Electromagnetic Safety, Institute of Electrical and Electronics Engineers (IEEE) in the USA.

In July 2015, the relevant Australian regulator (ARPANSA) officially adopted the more conservative of the above two, the ICNIRP 2010 Guidelines, in full, stating:

> "*The ICNIRP ELF guidelines are consistent with ARPANSA's understanding of the scientific basis for the protection of the general public (including the foetus) and workers from exposure to ELF EMF*." (Ref. C-2)

In line with the regulator's advice, Aurecon has applied the provisions of the current international ICNIRP Guidelines to this assessment.

The 'Basic Restrictions' and 'Reference Levels'[15] for both electric and magnetic fields, contained in the current ICNIRP Guidelines' are summarised in the table below.

Table C 1: ICNIRP Guideline Levels

Parameter	Basic Restriction (Volts per metre)	Reference Level
Electric field – general public	CNS Tissue of the head: 0.02 All tissue of head & body: 0.4	5,000 Volts per metre (V/m)
Magnetic field – general public	CNS Tissue of the head: 0.02 All tissue of head & body: 0.4	2,000 milligauss (mG)
Electric field – occupational	CNS Tissue of the head: 0.1 All tissue of head & body: 0.8	10,000 Volts per metre (V/m)
Magnetic field – occupational	CNS Tissue of the head: 0.1 All tissue of head & body: 0.8	10,000 milligauss (mG)

In applying the guidelines, it is to be noted that, unlike earlier versions, the various limits are now independent of duration of exposure.

In applying the ICNIRP Guidelines, it is also important to recognise that the numerical limits, eg 2,000 mG, are based on established health effects. In ICNIRP's fact sheet on the guidelines (Ref. C-3), it notes that:

> "*It is the view of ICNIRP that the currently existing scientific 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 for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well-established adverse effects and serve as the basis for guidance.*"

Being based on established biological effects (which occur at field levels much higher than those normally encountered in the vicinity of electrical equipment), the (numerical) exposure limits in the guidelines and standards cannot be said to define safe limits for possible health effects, should these exist, from magnetic fields at levels normally encountered in the vicinity of electrical equipment.

It is in this context that precautionary measures for ELF magnetic fields such as prudent avoidance have arisen (refer Appendix D).

References

C-1 International Commission on Non-Ionising Radiation Protection (2010: Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz): *Health Physics* 99(6):818-836; (2010).

C-2 ARPANSA: *Extremely Low Frequency Electric and Magnetic Fields* – 2015, accessed 10 May 2016.

C-3. ICNIRP Fact Sheet on the guidelines for limiting exposure to time-varying electric, and Magnetic Fields (1Hz-100kHz) published in *Health Physics* 99(6): 818-836; 2010, accessed 10 May 2016, <http://www.icnirp.org/cms/upload/publications/ICNIRPFactSheetLF.pdf>.

Appendix D
Prudent avoidance

Extremely low frequency magnetic fields

Regarding the potential health effects from ELF magnetic fields, while compliance with the relevant guideline is important in protecting people from established health effects, it does not necessarily address possible health effects, should they exist, from fields at levels normally encountered in the vicinity of electrical equipment. The possibility of such effects has been comprehensively studied over several decades worldwide but, to this day, there is no clear understanding of how ELF electric or magnetic fields at low levels could pose a threat to human health.

Since the late 1980s, many reviews of the scientific literature have been published by authoritative bodies. There have also been several inquiries such as those by Sir Harry Gibbs in NSW (Ref. D-1) and Professor Hedley Peach in Victoria (Ref. D-2). These reviews and inquiries have consistently found that:

- adverse health effects have not been established for fields at levels commonly found around electrical equipment and infrastructure;
- the possibility cannot be ruled out; and
- if there is a risk, it is more likely to be associated with the magnetic field than the electric field.

Both Sir Harry Gibbs and Professor Peach recommended a policy of prudence or prudent avoidance, which Sir Harry Gibbs described in the following terms:

> "*… [doing] whatever can be done without undue inconvenience and at modest expense to avert the possible risk …*"

In 1999, the (US) National Institute of Environmental and Health Sciences (NIEHS) (Ref. D-3) found:

> "*In summary, the NIEHS believes that there is weak evidence for possible health effects from ELF-EMF exposures, and until stronger evidence changes this opinion, inexpensive and safe reductions in exposure should be encouraged*." (page 38)

The practice of prudent avoidance has been adopted by the (Australian) Energy Networks Association (ENA) and most Australian power utilities.

The World Health Organization has also addressed the notion of prudence or precaution on several occasions, including in its 2007 publication *Extremely low frequency fields. Environmental Health Criteria, Vol. 238* (Ref. D-4), which states:

> "*…the use of precautionary approaches is warranted. However, it is not recommended that the limit values in exposure guidelines be reduced to some arbitrary level in the name of precaution. Such practice undermines the scientific foundation on which the limits are based and is likely to be an expensive and not necessarily effective way of providing protection*."

It also states:

> *"Provided that the health, social and economic benefits of electric power are not compromised, implementing very low-cost* precautionary *procedures to reduce exposure is reasonable and warranted.*"

Given the inconclusive nature of the science, it is considered that a prudent approach continues to be the most appropriate response in the circumstances. Under this approach, subject to modest cost and reasonable convenience, power utilities and transport authorities should design their facilities to reduce the intensity of the fields they generate, and locate them to minimise the fields that people, especially children, encounter over prolonged periods. While these measures are prudent, it cannot be said that they are essential or that they will result in any benefit.

In the Australian context, ENA's position, as adopted in their *EMF Management Handbook* (Ref. D-5), states:

> "*Prudent avoidance does not mean there is an established risk that needs to be avoided. It means that if there is uncertainty, then there are certain types of avoidance (no cost/very low cost measures) that could be prudent*."

It also states:

> "*Both prudent avoidance and the precautionary approach involve implementing no cost and very low cost measures that reduce exposure while not unduly compromising other issues*."

References

D-1. Gibbs, Sir Harry, Chairman, I*nquiry into Community Needs and High Voltage Transmission Line Development, Submission to the NSW Government*, February 1991.

D-2. Peach HG, Bonwick WJ and Wyse T (1992). *Report of the Panel on ElectroMagnetic Fields and Health to the Victorian Government (Peach Panel Report)*. Melbourne, Victoria: September 1992.

D-3. National Institute of Environmental Health Sciences, National Institutes of Health, (USA), *NIEHS report on health effects from exposure to power-line frequency electric and Magnetic Fields*, NIH Publication No. 99-4493, 1999.

D-4. World Health Organization*: Environmental Health Criteria* Vol. 238: Extremely low frequency fields. (2007).

D-5. Energy Networks Association: *EMF Management Handbook*. (2016)

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