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Summary of the Literature: Wind Farms and Health

AECOM

the long view group

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EXECUTIVE SUMMARY

The Long View Group (TLVG) has been commissioned by AECOM on behalf of AGL to present an overview of the scientific evidence on the human health impacts associated with wind farms for the Coopers Gap Wind Farm Project (the Project). The scope of this report is to provide a summary of the reviewed literature on the following topics as it relates to wind farms and human health:

- Noise (audible, infrasound, low frequency sound);
- Shadow flicker; and
- Electromagnetic radiation.

Due to the climate of the project site, ice throw from wind turbines was not included in the review. The report was also required to compare the wind farm sites studied in the reviewed literature and the Project to assess whether the key findings were likely to be applicable.

This report intends to provide a fact based presentation of key findings of the peer reviewed scientific literature on wind farms and health, noting that this report is not a systematic or comprehensive review of the scientific literature to the quality undertaken by academic researchers.

Selection criteria were applied to short list references for inclusion in this report. This involved identifying key publications by public health agencies in Australia, creating a full list of references based on their bibliographies and shortlisting this full list to only include peer reviewed journal articles and publications by public health agencies related to wind farms and health. Through this process 47 references were identified for detailed review in this report. These references include epidemiological studies of wind farms and health (direct evidence) as well as a number of other studies that provide useful information on exposure and disease where the direct evidence is limited (background evidence).

The recent publications by the National Health and Medical Research Council (NHMRC 2010, 2014) and recent systematic literature reviews undertaken by the Adelaide University (Merlin et al, 2013) and Massachusetts research team (Ellenbogen et al, 2012) were key publications and references for this report.

Before presenting the key findings of the scientific literature on wind farms and health an appraisal of the quality of the available evidence was provided. Drawing on the assessments undertaken by the Adelaide and Massachusetts researchers in their separate literature reviews, this report found that there are limited epidemiological studies available on wind farms and health, the quality of the studies is low due to the methodological design of the research and it would be difficult to use the direct evidence to present conclusions with any high level of confidence due to these issues.

The conclusions and public statements by a number of Australian and international public health agencies and academic researchers on wind farms and health were provided in the report. The general consensus is that there is no scientific evidence of an association between exposure to wind farms and adverse health impacts. This applies to noise, low frequency noise, infrasound, shadow flicker and electromagnetic radiation.

This is further detailed in the key findings of the reviewed literature on wind farms and health as follows:

Noise

In the reviewed literature, the health impacts associated with audible noise from wind farms has attracted the most peer reviewed epidemiological studies in the field, noting that this is still a limited number (six studies published in 11 articles). The overall quality of these epidemiological studies on wind farms and health is rated as low due to methodological issues such as the selection bias of respondents and self-reporting of health impacts.

The key finding from the reviewed literature is that there is no scientific evidence that exposure to wind farm noise can cause adverse health impacts. While there is evidence that some people living in proximity to a wind farm may experience annoyance, there is no consistent evidence that wind farm noise directly causes annoyance, and it may be that these people's annoyance stems from a number of factors including negative attitudes to the project.

Infrasound

In the reviewed literature, the health impacts associated with infrasound from wind farms has not attracted any peer reviewed epidemiological studies. A number of peer reviewed acoustic studies have been undertaken however.

The key finding from the reviewed literature is that there is no scientific evidence that exposure to wind farm infrasound can cause adverse health impacts. Levels of exposure to wind farm infrasound have consistently been found to be below the 85dBG threshold of human perception. There is no evidence of physiological effects from infrasound that is below the level of audibility. The infrasound emitted by wind farms has been found to be comparable to a number of other sources including coastlines, urban areas and other industrial processes.

Low Frequency Sound (or noise)

In the reviewed literature, the health impacts associated with low frequency sound from wind farms has not attracted any peer reviewed epidemiological studies. A number of peer reviewed acoustic studies have been undertaken however.

The key finding of the reviewed literature is that there is no scientific evidence that exposure to wind farm low frequency noise causes adverse health impacts. The amplitude modulating characteristics of wind farm noise (also referred to as 'swooshing') that have anecdotally been associated with annoyance are in the mid-high frequency range and would be measured through standard dBA noise assessments.

Shadow Flicker

In the reviewed literature, the health impacts associated with shadow flicker from wind farms has not attracted any peer reviewed epidemiological studies.

The key finding of the reviewed literature is that there is no scientific evidence that wind farm shadow flicker can cause adverse health impacts. There is negligible risk of seizure from modern three bladed wind turbines which rotate at a speed that is below the level to elicit a seizure response in photosensitive individuals.

International guidelines for layout and design of wind turbines are in place to reduce the potential for shadow flicker to cause annoyance.

Electromagnetic Radiation

In the reviewed literature, the health impacts associated with EMR from wind farms has not attracted any peer reviewed epidemiological studies.

The key finding of the reviewed literature is that there is no scientific evidence that wind farm EMR can cause adverse health impacts. There is anecdotal evidence that wind farms generate EMR at the same level as household appliances but no peer reviewed studies to confirm this is the case.

In order to assess whether the key findings of the reviewed literature were likely to be applicable to the proposed Coopers Gap Wind Farm Project, a high level comparison was undertaken between the wind farm sites studied in the reviewed literature and the Project. It was found that the studies in the reviewed literature were based on modern three blade wind turbines in rural landscapes. There were differences in size and number of turbines and adjacent population however, it would be likely that the key findings would be relevant to the Project.

AGL has undertaken a number of assessments for the proposed Coopers Gap Wind Farm project covering the issues of turbine design, noise, infrasound, low frequency noise and shadow flicker and electromagnetic interference. These assessments have confirmed that the proposed wind farm would operate within recommended Australian guidelines for these factors. The assessments are published in the Revised Assessment Report for the Project.

GLOSSARY

Acoustics: The science that deals with the study of the generation, transmission and reception of sound, ultrasound and infrasound.

Aerodynamic sound: For wind turbines, the sound generated by the interaction of the blade trailing edge, tip or surface with air turbulence.

Annoyance: An unpleasant mental state characterised by effects such as irritation and distraction from one's conscious thinking.

Association: Statistical dependence between two or more events, characteristics or other variables.

Background evidence: Includes evidence obtained from related fields that support the association between an exposure of interest and an adverse health effect (parallel evidence) and evidence for a mechanism by which an exposure of interest may cause a particular health outcome of interest (mechanistic evidence); the mechanism may be biological, chemical or mechanical.

Bias: The effect of an error in the design of a study or an error or problem in the collection, analysis, reporting, publication or review of study data that leads to untrue results.

Cross-sectional study: A study that examines the relationship between diseases (or other health-related characteristics) and other variables as they exist in a defined population at one particular time.

Decibel: A unit of measure used to express the loudness of sound, calculated as the logarithmic ratio of sound pressure level against a reference pressure.

Direct evidence: Evidence directly linking an exposure with a health outcome of interest.

Electromagnetic radiation (EMR): Radiation that is a combination of electric and magnetic waves (such as X-rays, ultraviolet rays, infrared rays, visible light and radio waves) transmitted in a wave-like pattern as part of a continuous spectrum of radiation.

Epidemiology: The study of the patterns, causes, and effects of health and disease conditions in human populations.

Exposure: For this review, exposure relates to being in the vicinity of wind farm emissions.

Frequency: The number of sound waves or cycles passing a given point per second; measured in cycles per second and reported in Hertz (1 Hertz = 1 cycle per second).

Hertz: A measure of frequency. 1 cycle per second = 1 Hertz.

Infrasound: A term used to describe sound in the frequency range lower than 20 Hertz.

Low-frequency sound: Sound that falls within the frequency range of 20 to 200 Hertz.

Mechanical sound: For wind turbines, the sound produced by the interaction of electrical and rotational parts such as gearbox and generator.

Noise: Unwanted sound or a combination of sounds.

Peer-reviewed literature: Published literature that, before it was published, was reviewed critically by other people in the same field of research and revised in response to the critical review as a condition of publication.

Selection bias: Distortions in outcomes that result from the procedures used to select participants and from factors that influence participation in a study.

Self-report: Information on a person's history or personal characteristic that a person them self provides, generally from memory.

Shadow flicker: The flickering effect caused when rotating wind turbine blades intermittently cast shadows over neighbouring properties as they turn.

Sound pressure level: A measure of the sound pressure of a sound relative to a reference value, measured in decibels (dB).

Sound: An energy form that travels from a source in the form of waves or pressure fluctuations, transmitted through a medium (e.g. air, water), and received by a receiver (e.g. human ear).

Systematic literature review: A process that provides a transparent and reproducible means for gathering, synthesising and appraising the findings of studies on a particular topic or question. The aim is to minimise the bias associated with the findings of single studies or non-systematic reviews.

Wind farm: A collection of wind turbines.

Wind turbine: A device that uses kinetic energy from the wind to produce electricity.

(Glossary adapted from NHMRC, 2014)

1. INTRODUCTION

The Long View Group (TLVG) has been commissioned by AECOM on behalf of AGL to present an overview of the scientific evidence on the human health impacts associated with wind farms for the Coopers Gap Wind Farm Project (the Project). The review will form the basis of the Socio Economic assessment for the proposed Coopers Gap Wind Farm Project (the Project).

This literature review has also been prepared in response to submissions received as part of the initial consultation and ongoing engagement for the Project. The project has received 12 submissions in total relating to the potential impact on human health from the wind farm development. References for this literature review have been drawn from peer reviewed journals and publications by national research and government organisations. The literature review will form an Appendix to the Socio-Economic Chapter of the Coopers Gap Wind Farm Revised Assessment Report.

1.1. THE PROJECT

The Project is located near Cooranga North, in central southern Queensland 180 kilometres (km) north-west of Brisbane. The proposed installed capacity of the wind farm is up to 556 megawatts generated from up to 139 turbines, each turbine of 2 – 4 MW capacity. The existing land use within and around the proposed project is predominantly rural, characterised largely by cattle grazing. The project study area covers approximately 10,200 hectares and involves ten landowners. The closest township is Bell, which is located 15 km south of the site with a population of 300 people.

1.2. SCOPE OF THIS REVIEW

The scope of this report is to provide a summary of the reviewed literature on the following topics as it relates to wind farms and human health:

- Noise (audible, infrasound, low frequency sound);
- Shadow flicker; and
- Electromagnetic radiation.

Due to the climate of the project site, ice throw from wind turbines was not included in the review of human health impacts.

The report is also required to compare the wind farm sites studied in the literature and the proposed Coopers Gap Wind Farm Project to assess whether the key findings of the literature are likely to be applicable.

Information from the AGL Coopers Gap Initial and Revised Assessment Reports has been used to provide context to this report.

1.3 ASSUMPTIONS AND LIMITATIONS

This report intends to provide a fact based and objective summary of key findings of peer reviewed scientific literature on wind farms and health.

Peer reviewed studies published in scientific journals on wind farms and health are considered the best available scientific evidence due to the independent review process required for publication. Publications by national and state-level public health agencies are also considered both credible and high quality due to their independent community role and the internal organisational review process.

In this report a transparent process for selecting the references to be included in the review has been applied. This involved identifying key publications by public health agencies in Australia and using their bibliographies to create a list of references for this report. The National Health and Medical Research Council (NHMRC) Draft Information Paper 2014 was the primary source of information due to the proportion of peer reviewed journal articles included in their literature review. The NHMRC has drawn on direct and background evidence in their literature review. Direct evidence refers to epidemiological studies on wind farms and health. Background evidence refers to a range of studies that may or may not be related to wind farms or health but provide information that is useful to informing the key findings particularly in areas where direct evidence may be limited.

The appraisal of the validity and quality of individual epidemiological studies on wind farms and health presented this report is based on assessments by the NHMRC and two recent and comprehensive literature reviews on the subject (Merlin et al, 2013 and Ellenbogen et al, 2012).

1.4 STRUCTURE OF THE REPORT

This report is divided into seven main sections:

Section 1: Provides the introduction to the study and the scope, assumptions and limitations associated with the review.

Section 2: Presents the references that were chosen for review in this report. These include peer reviewed journal articles and publications commissioned or authored by public health and government agencies. Following a brief overview of epidemiology as a field of science, an appraisal of the quality of the available evidence is provided.

Section 3: Provides an overview of wind farms emissions that have anecdotally been associated with health impacts and are addressed in the reviewed literature. These include noise, shadow flicker and electromagnetic radiation.

Section 4: Presents the key findings and conclusions on the scientific evidence on wind farms and human health published by public health agencies and academic researchers from Australia and internationally.

Section 5: Provides a summary of the scientific evidence on wind farms and health based on the reviewed literature. Direct evidence and background evidence have been used to inform this overview. Information is presented in terms of levels of acceptable exposure, key issues, scientific evidence and key findings.

Section 6: Provides a high level comparative assessment of the relevance of the scientific evidence presented in Section 5 to the Coopers Gap Wind Farm Project. This involves comparing the study parameters of the reviewed literature with the Project (e.g size of wind farm and location of residents).

Section 7: Summarises the key findings of this report.

Appendix A: Presents the full and short-listed list of references identified for use in this report. A brief statement on the content of each reference is also included.

2. LITERATURE REFERENCES, EPIDEMIOLOGY AND QUALITY OF EVIDENCE

This section describes the process for selecting literature to be reviewed in this report. It also draws on the systematic literature reviewed undertaken by groups such as the NHMRC, the Adelaide University and the Massachusetts researchers to assess the quality of evidence available on the subject of wind farms and health.

Peer reviewed studies published in scientific journals on wind farms and health are considered the highest quality and most credible information in circulation. These studies and articles are subject to review by independent experts in the field and need to meet high standards of reliability and validity. Authors of these studies are primarily academics, however, practitioners have also published in journals.

Publications and statements by public health organisations on the issue of wind farms and health are also considered both credible and high quality due to their reputation and profile but also due to their broader community role and internal organisational peer review processes undertaken to scrutinise information before it is publicly issued.

2.1. SELECTION OF LITERATURE

Figure 1 provides an overview of the process used to select references for this report.

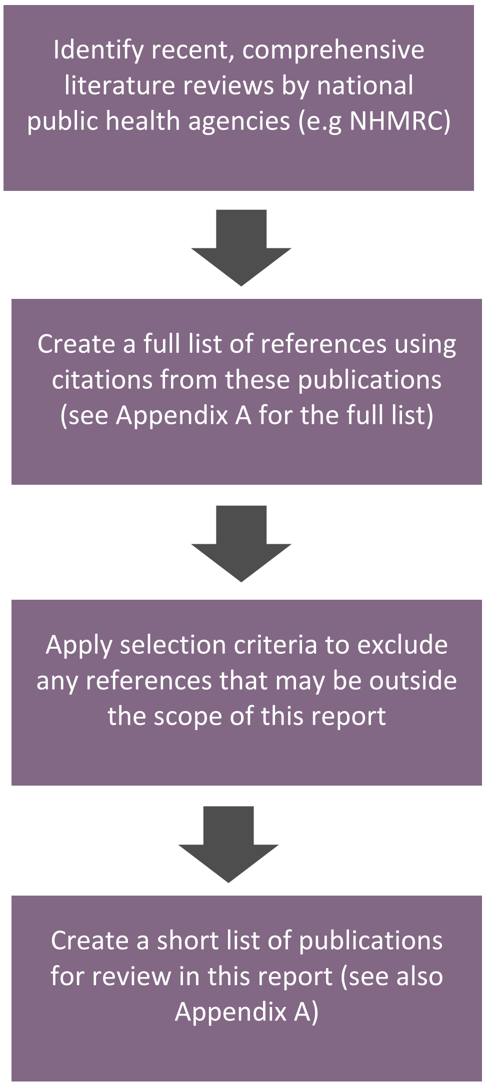

Figure 1: Literature selection process

The public health agencies in Australia that have published statements or publications on the subject of wind farms and human health include:

- The NHMRC which is the national agency in Australia that is concerned with the development and maintenance of public and individual health standards and provides advice to Australian using the best available, scientific evidence (www.nhmrc.gov.au). It has published a *Draft Information Paper: Evidence of Wind Farms on Human Health* (Feb, 2014) and *Wind Turbines and Health: A Rapid Review of Evidence* (2010);
- The Australian Medical Association (AMA) which is the peak organisation in Australia representing registered doctors and medical students (www.ama.com.au) has published a *Position Statement on Wind Farms and Health* (2014); and
- The Public Health Association of Australia (PHAA) is the national organisation in Australia representing individual members and professional groups concerned with public health (www.phaa.net.au) has published a *Position Statement on the Human Health Effects of Wind Turbines* (2011).

The public statements and key findings of each of these agencies are based on a review of the literature and are presented in Section 4. The NHMRC and PHAA have included the references that informed their key findings and these have been provided in Appendix A to create the full list of references for this report. A total of 79 references were identified through this process. The NHMRC *Draft Information Paper* 2014 references in particular have undergone rigorous analysis, peer review and assessment for inclusion and represent the best available scientific evidence. The NHMRC Draft Information Paper was informed by a detailed systematic review of the literature undertaken by the Adelaide Technology Assessment Team from Adelaide University (see Merlin et al, 2013).

Not all of the references used by NHMRC and PHAA have been reviewed in detail in this report. Those references that have been excluded from this review include those that are not peer reviewed journal publications or publications by public health agencies or studies that relate to general methodological guidelines or public health studies outside the scope of this report. The selection criteria for inclusion of literature reviewed in this report were as follows:

- Is the study a peer reviewed journal article?
- Is the study research commissioned or authored by a public health or Government agency?
- Is the study relevant to wind farms and health?

Applying these selection criteria, the full list of references was narrowed down to 47 for review and inclusion in this report and is referred to throughout this report as the ‘reviewed literature’. Appendix A provides the full list of references, a brief statement on their content, as well as the results of the selection criteria process.

2.2. EPIDEMIOLOGY

It is important to clarify what is meant by epidemiological studies and how they are used to provide direct evidence of any association between wind farms and adverse human health effects.

Epidemiology is concerned with the causal relationship between exposure and disease. It is defined in the Oxford Dictionary as "The branch of medicine which deals with the incidence, distribution, and possible control of diseases and other factors relating to health". In their report to the Wisconsin Public Service Commission, Roberts et al (2009) provide an overview of the scientific process and the role of epidemiological studies to determine a causal relationship between exposure and disease. They note a number of factors that contribute to the weight of evidence. These include:

- The association between two variables needs to be clear and not be attributable to chance;
- There needs to be a number of criteria that are used to test the significance of the causal relationship;
- Evidence is strengthened when several epidemiological studies performed by different researchers result in the same conclusions; and
- Researchers submit their studies for publication in journals which requires a peer review process for scientific soundness.

According to Roberts et al (2009) the process for determining association and causality is generally determined by a linear scientific method that starts with clinical observations and moves through case reports and scientific questions to epidemiological studies and evaluation of causation. An overview of this process is provided in Figure 2 on the following page.

Closely related to the field of epidemiology is the concept of public health. Public health is defined by the World Health Organization (WHO) as "all organized measures (whether public or private) to prevent disease, promote health, and prolong life among the population as a whole. Its activities aim to provide conditions in which people can be healthy and focus on entire populations, not on individual patients or diseases". Public health therefore is primarily concerned with populations and a broad range of actions that improve the health of individuals within these populations.

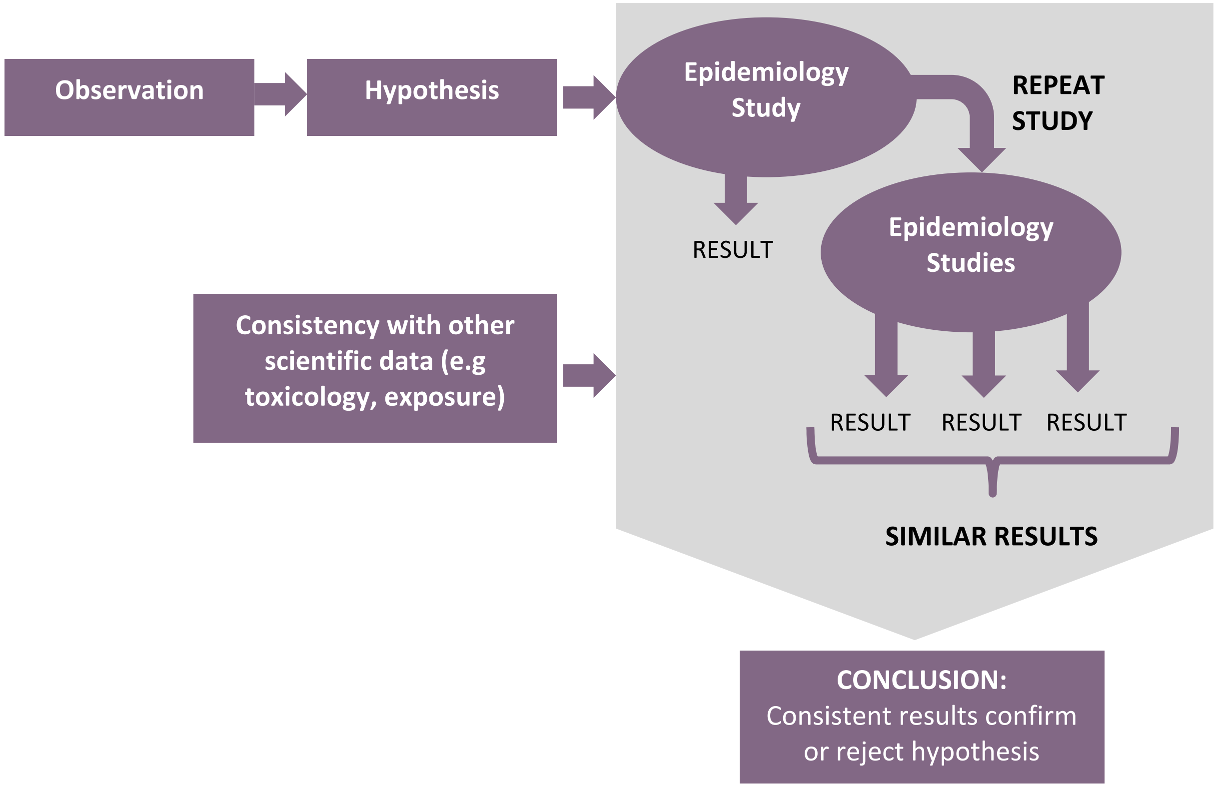

Figure 2: Scientific method (Roberts et al, 2009)

2.3. QUALITY OF THE EVIDENCE

Understanding the quality and validity of the scientific evidence available on wind farms and health gives an indication of the extent to which these studies provide a consistent weight of evidence in support of their conclusions. Within the last two years, two organisations have undertaken comprehensive literature reviews in relation to wind farms and health and have also included a detailed appraisal of the available scientific evidence. The two resulting publications are:

- The NHMRC commission of Adelaide Health Technology Assessment *Systematic Review of Human Health Effects of Wind Farms* (Merlin et al, 2013); and
- The Massachusetts State Government commission of an independent panel of experts *Wind Turbine Health Impact Study: Report of independent expert panel* (Ellenbogen et al, 2012).

Given the recent timing and the technical rigour applied to these reviews, they have been taken as key sources of literature for this peer review. Both reviews are described in the following sections.

2.3.1. NHMRC/ADELAIDE HEALTH TECHNOLOGY ASSESSMENT STUDY

The NHMRC is the national agency that provides the best available, evidence based advice on matters relating to health and preventing, diagnosing and treating disease. The NHMRC states that due to some members of the community reporting that living near a wind farm has affected their health they have investigated whether there is any reliable evidence of an association. In 2010 the NHMRC published a *Rapid Review of the Evidence* concluding that "There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines". Noting the limited publications available for the 2010 study they committed to carrying out a more extensive review. The NHMRC commissioned the Adelaide Health Technology Assessment (AHTA) located at the Adelaide University to conduct an independent review of the scientific evidence on wind farms and health. This process was guided by an NHMRC reference group led by Professor Bruce Armstrong from the School of Public Health in the University of Sydney and included a number of other academics and technical experts.

The NHMRC Reference Group developed systematic and background review questions for the Adelaide research team to address in the literature review. The systematic review questions required a review of direct evidence that health impacts are related to distance from and exposure to any emissions from wind farms. This involved careful selection of literature sources and presenting scientific analysis of the highest quality while minimising the effects of bias from single studies. The background literature review by contrast examined a range of questions including likely levels of exposure, whether it was plausible that wind farm emissions may affect health (mechanistic evidence) and whether any health effects have been observed by these emissions when produced by sources other than wind farms (parallel evidence) (NHMRC 2014). The background review questions sought general knowledge and were not intended to be answered as comprehensively as the systematic review questions (Merlin et al, 2013 p.21-3).

2.3.1.1 AHTA Approach to Systematic Literature Review

As outlined in the AHTA report, a total of 1,778 articles were identified through a systematic search of the peer reviewed literature; 1,070 of these documents were found by searching the non-peer reviewed literature. The NHMRC called for documents to identify any additional references to include in the literature review and identified an additional 506 documents. The following selection criteria were then applied to all these documents:

- Were they publicly available?
- Did they describe systematic collection and analysis of data?
- Were reported analytical results relevant to wind farms and health?
- Did observations involve organisation and analysis?
- Were they based on the results of the research and not an expressed opinion?
- Were they solely or haphazardly collected or unstructured personal testimony?

As a result of this rigorous selection process, the Adelaide research team identified only seven studies presented in 11 articles for inclusion as direct evidence in the systematic review. One non-peer reviewed study was from Australia (Morris, 2012) and six related peer reviewed studies were from the Netherlands (Bakker et al., 2012), Canada (Krogh et al, 2011), New Zealand (Shepherd et al, 2011), Sweden (Pedersen et al, 2004; Pedersen et al, 2007) and the United States of America (Nissenbaum et al, 2012). All these references are included as part of the reviewed literature of this report as they were cross-referenced by the NHMRC (excluding Morris which included in the full list but not short listed for detailed review because it is a non-peer reviewed study).

In addition to the above selection criteria process, the Adelaide researchers used an adapted version of the NHMRC Evidence Statement FORM Grading System (2009) to appraise the quality of these seven studies in terms of methodological rigour and level of evidence and likelihood of bias and confounding factors. The researchers concluded that all the studies were rated as poor quality or D (on a scale of A - D).

The reasons Merlin et al (2013) provided for this appraisal of 'poor quality' primarily relates to the design of the studies. The studies used cross-sectional design which meant that pre-existing health issues of the study population were not known and their health status was not independently verified. The survey response approach used in the studies would likely result in selection bias of the study population especially when the purpose of the study was not adequately masked. Also, the cause of reported health effects were not clear cut and were possibly associated with a number of confounding factors.

As summarised in the AHTA report, the seven studies primarily reported on the association between estimated noise levels or distance from wind turbines and self-reported adverse health effects. None of these studies specifically reported on issues related to infrasound or low frequency sound. Only one non-peer reviewed study examined shadow flicker and no studies examined electromagnetic radiation. The six peer reviewed studies were included in the reviewed literature for this report as they were cross-referenced in the NHMRC report and met the short list criteria.

2.3.1.2 AHTA Approach to Background Questions

A broad literature review was used to identify references for the background questions and also provide parallel and mechanistic evidence. Literature sources referred to for this purpose included over 100 peer-reviewed studies, technical reports and analyses produced by expert panels and environmental health agencies.

Nine studies were examined in detail to provide parallel or mechanistic evidence in relation to health impacts from wind farms where direct evidence was not available. These included the literature review commissioned by the Massachusetts Government (Ellenbogen et al, 2012), relevant publications by the World Health Organisation (2002, 2011, 2012) a number of epidemiological studies of infrasound and low frequency sound that were not specific to wind farms (Danielsson et al, 2009; Alford et al, 1966 and Mills et al, 1983) and one acoustic study of infrasound from wind farms (Evans et al, 2013). These nine studies were included in the reviewed literature for this report as they were cross-referenced in the NHMRC report and met the short list criteria.

2.3.2. MASSACHUSETTS INDEPENDENT PANEL STUDY

In 2012, the Massachusetts Department of Environment Protection and Department of Public Health convened an expert panel of eight medical and research doctors from academic institutions such as the Harvard Medical School and Boston University School of Public Health. The panel was convened to identify any connection between health impacts and wind farms and outline best practices to manage these impacts.

The literature review process involved extensive searches to identify studies that specifically evaluate population responses to wind turbines as well as population and individual responses to issues such as noise, vibration and flicker. The panel also reviewed non-peer reviewed material including documents related to 'Wind Turbine Syndrome' and assessed them for their scientific rigour. The panel relied on human epidemiological studies specifically related to wind turbines as well as animal studies.

In reviewing the literature for strength of evidence and validity of findings, the researchers only found four peer reviewed articles (the aforementioned Swedish, Dutch and New Zealand studies in Section 2.3.1) that met their criteria. They also identified four non-peer reviewed articles that met their criteria; two of which have been included in the reviewed literature of this report: Van den Berg et al, 2009 is included because it was undertaken for the European Union and Nissenbaum et al, 2011 was subsequently published in a journal.

In appraising the eight studies selected for inclusion as direct evidence in the literature review, the Massachusetts researchers assessed their quality as low. They summarise their appraisal as follows (Ellenbogen et al, 2012, p.27):

"There is only limited literature of epidemiological studies on health effects of wind turbines. Furthermore, the existing studies are limited by their cross-sectional design, self-reported symptoms, limited ability to control for other factors, and to varying degrees of non-response rates."

Similar to the Adelaide team, the Massachusetts researchers drew upon a range of background studies to inform their assessment of specific exposures associated with wind farms including noise and vibration, shadow flicker and ice throw. This included animal studies conducted in areas such as high level exposure to infrasound and low frequency sound, general studies regarding the impact of sleeplessness on chronic health effects and several studies relating to shadow flicker. The study did not examine health impacts associated with electromagnetic radiation.

In summary, the quality of the available evidence as assessed by two separate literature reviews that were commissioned by public health agencies and subject to detailed review and analysis shows:

- There are limited epidemiological studies available for determining a direct association between wind farms and human health effects which brings into question the weight of the evidence;
- The quality of this epidemiological literature is rated as low due to the methodologies employed; and
- It would be difficult to use the direct evidence to present conclusions with any high level of confidence due to the above issues.

3. WIND FARM EMISSIONS AND HEALTH

This section summarises the emissions of wind farms that have been associated with potential human health impacts in the popular literature and media and have subsequently been assessed for validity in the peer reviewed literature.

In their review of the literature, the expert panel commissioned by the Massachusetts Government (see Section 2.3) provide a detailed overview of how wind farms operate and generate electricity (Ellenbogen et al, 2012). Discussing the technical process of how wind farms convert kinetic energy into a mechanical form; they note that the design of wind turbines has evolved over the years in response to a range of efficiency, environmental and safety issues. This evolution has resulted in the tall cylindrical structures and large three bladed rotors that are the hallmark of the modern wind farm as shown in Figure 3.

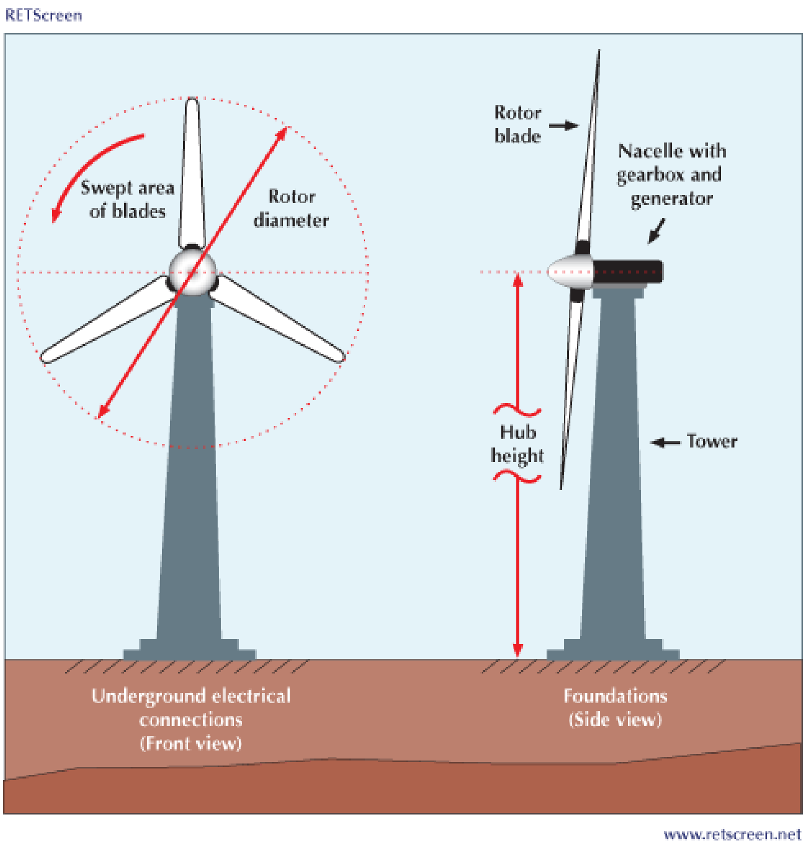

Figure 3: Wind Turbine in Operation (cited in Roberts et al, 2009)

The emissions or impacts of wind farms that have been identified with adverse health effects in the popular literature and have been assessed for validity in the scientific peer reviewed literature include (see for example, NHMRC, 2014; NHMRC, 2010a; Merlin et al, 2013; Ellenbogen et al, 2012; Rideout et al, 2010):

- Noise and vibration from turning blades of the wind turbine;
- Shadow flicker and blade glint from the turning blade of the wind turbine reflecting the sun;
- Electromagnetic radiation from the conversion of wind energy to electricity; and

- Ice throw from ice shards that collect and drop from turning wind turbine blades.

However, not all studies in the reviewed literature have examined these four emissions and their potential impacts to the same level of detail. Ellenbogen et al (2012) for example do not consider electromagnetic radiation (EMR) in their key findings; and the NHMRC (2010b, 2014) and ATHA researchers (Merlin et al, 2013) do not consider ice throw. It would be appropriate to assume that ice throw is not relevant to the climate of the Project site and therefore does not warrant further discussion in this report.

3.1. WIND TURBINE NOISE

The reviewed literature contains a large number of studies that have sought to define and describe the noise from wind turbines (see Appendix A). Wind turbines are observed to produce both mechanical and aerodynamic noise. Mechanical noise is produced from the mechanical elements of the wind turbine such as the gearbox, generator, cooling fans or hydraulics. The types of sounds associated with mechanical noise are tonal (where there is a dominant low or high frequency sound), grinding or vibrational. Aerodynamic noise is produced by the rotation of the turbine blades through the air. The types of sounds associated with aerodynamic noise include tonal, broadband, low frequency, amplitude modulation (whooshing or beating sound) and infrasonic (Ellenbogen et al, 2012; Evans et al, 2013; NHMRC, 2010b). According to Ellenbogen et al (2012), mechanical noise is generally not a concern for the community as modern wind turbines have been designed to significantly reduce mechanical noise impacts on the environment.

According to the NHMRC and a study conducted by Evans et al for the South Australian Environment Protection Agency (2013), humans can hear sounds at varying levels of frequencies and sound pressures. A high pitch is generally used to describe a high frequency and a low pitch is used to describe a low frequency. However pitch is also affected by loudness which determines how the person experiences the sound. The main frequencies include:

- Sounds in the frequency range 0 – 20 hertz (Hz) are considered infrasound and are generally not perceptible to the human ear except at very loud levels;
- Sounds in the frequency range 20 –200 Hz are termed low frequency sound and may be perceptible by different people depending on their noise sensitivity; and
- Sounds between 200 – 20,000 Hz can normally be heard by different people depending on their noise sensitivity and the level of loudness.

The Victorian Health Department in their publication *Wind Farms Sound and Health* (2013) provides a useful overview of the different aspects of sound associated with wind farms. They note that when measuring sound, the sound pressure level expressed as a decibel (dB) is weighted toward frequencies that are more likely to be heard. This process is referred to as A-weighting and presents a value for the level of sound in terms of dBA. The dBA is the common measurement for determining when a sound or combination of sounds reaches a certain threshold and may be experienced by a person or the community as unwanted sound or “noise”.

They further state that hearing thresholds for infrasound are measured using a G-weighted network which has been developed to measure sounds in the infrasound range presented as a unit of dBG. C-weighted networks (dbC) have been used to measure sound with a significant low frequency component.

The NHMRC (2014) notes that the level of noise varies with background noise, distance from the sound, weather conditions, the type of wind turbine and the terrain and that any assessment of noise levels would need to take these factors into account.

Table 1 provides an overview of the different sources that can be associated with increasing decibel levels. To put the table in perspective it is useful to note that Project has assessed potential sound at 45dBA may be heard at 600 – 700 m from the turbine (Coopers Gap Revised Assessment Report).

Table 1: Human Sound Level Intensities

Decibel Level (dB)	Source
140	Threshold of pain, gunshot, siren at 100 feet
135	Jet take off, amplified music
120	Chain saw, jack hammer, snowmobile
100	Tractor, farm equipment, power saw
90	Hearing damage if excessive exposure to noise levels above 90dB
85	Inside acoustically insulated tractor cab
75	Average radio, vacuum cleaner
60	Normal conversation
45	Rustling leaves, soft music
30	Whisper
15	Threshold of hearing
0	Acute threshold of hearing

Source: Roberts et al, 2009 citing the US National Agricultural Safety Database, 1993

3.2. SHADOW FLICKER

A small number of studies in the reviewed literature have sought to define and describe shadow flicker (See Appendix A). Shadow flicker has been identified as occurring when the sun passes behind rotating blades of a wind turbine and casts moving shadows on the ground and on buildings with varying frequency rates and degrees of intensity. The effect is seen to be due to both geographical position and time of day and is defined as a flickering effect of the light from the sun (NHMRC, 2014, Ellenbogen et al, 2012). According to Harding et al (2008) the likelihood and duration of the effect of shadow flicker depends on a number of factors, including distance from the wind turbine, turbine height and diameter, time of year and weather conditions.

A phenomena that is closely related to shadow flicker is referred to as blade glint or flashing. This is where the sunlight is reflected from the blade to create an intermittent flashing effect that has the potential to distract people driving cars for example. However, Ellenbogen et al (2012) observe that blade glint is generally not a concern as modern wind turbines have been designed with low reflective blades to reduce this potential problem.

3.3. ELECTROMAGENTIC RADIATION

A very small number of studies in the reviewed literature have sought to define and describe electromagnetic radiation (See Appendix A). Merlin et al (2013) and Ellenbogen et al (2012) observe that electromagnetic radiation (EMR) is present in a range of mediums including x-rays, infrared rays and radio waves and consists of electric and magnetic energy that is transmitted in a wave like pattern. They outline that electromagnetic radiation due to the flow of electrical current (termed EML) is produced by common electrical household appliances such as vacuum cleaners and mobile phones as well electrical cabling and equipment.

In the context of wind turbines, EML is identified in the reviewed literature as being produced by the grid connection lines, turbine generators, electrical transformers and underground collectors and network cabling (Merlin et al, 2013, NHMRC, 2014, Rideout et al, 2010).

4. KEY FINDINGS OF PUBLIC HEALTH AND ACADEMIC ORGANISATIONS

Based on the references included in the reviewed literature, this section presents the position statements and key findings on wind farms and health published by public health agencies such as the NHMRC. It also includes the key findings of detailed literature reviews undertaken by academic organisations on behalf of public health or government agencies such as the AHTA (Adelaide University) and Massachusetts literature reviews.

4.1. KEY FINDINGS OF PUBLIC HEALTH AGENCIES

Public health and medical organisations in Australia such as the NHMRC (2014), AMA (refer AMA website), PHAA (refer PHAA website) and Victorian Department of Health (2013) have recently published position statements on the issue of health impacts associated with wind farms. Agencies from overseas such as the Minnesota Department of Health (2009) and The Chatham-Kent Public Health Unit Canada (2008) have also published similar reports and statements. Their statements and key findings are included below.

Box 1: NHMRC Draft Information Paper (abridged)

NHMRC found no consistent direct evidence that exposure to wind farms was associated with any health outcome. The few associations reported by individual studies could have been due to chance. Therefore NHMRC concluded there is no reliable or consistent evidence that wind farms directly cause adverse health effects in humans.

NHMRC found consistent direct evidence that proximity to wind farms was associated with annoyance and less consistently, with sleep disturbance and poorer quality of life.

The poor quality of the studies from which this evidence came, however, meant that selection and information bias and confounding were possible explanations for the associations observed. Therefore even though there was support for some of these associations in studies of effects of noise from other sources, NHMRC could not conclude that exposure to wind farm noise *causes* annoyance, sleep disturbance or poorer quality of life.

Box 2: AMA Position Statement (abridged)

The available Australian and international evidence does not support the view that the infrasound or low frequency sound generated by wind farms, as they are currently regulated in Australia, causes adverse health effects on populations residing in their vicinity. The infrasound and low frequency sound generated by modern wind farms in Australia is well below the level where known health effects occur, and there is no accepted physiological mechanism where sub-audible infrasound could cause health effects.

Individuals residing in the vicinity of wind farms who do experience adverse health or well-being, may do so as a consequence of their heightened anxiety or negative perceptions regarding wind farm developments in their area. Individuals who experience heightened anxiety or diminished health and well-being in the context of local wind farms should seek medical advice.

The reporting of 'health scares' and misinformation regarding wind farm developments may contribute to heightened anxiety and community division, and over-rigorous regulation of these developments by state governments.

Box 3: PHAA Position Statement (abridged)

Reviews of the literature to date have failed to identify any adverse physiological effects attributed to exposure to wind turbines, with the exception of those mediated by noise in a small proportion of exposed people, in whom symptoms may be related to perception, annoyance and pyscho-sociological factors. This view is most recently summarised in the literature by NHMRC, 2010 and Knoppfer and Ollsen, 2011.

There is no evidence to date to suggest that infrasound has significant effects on human health via physiological mechanisms at the low pressure levels generated by wind turbines.

Box 4: Department of Health (VIC) Key Findings (abridged)

The predominant sounds produced by wind farms are in the mid to high frequencies. Wind farm sound, including low levels of low frequency sound, may be audible to nearby residents.

Audible noise from any source, including wind farms, can cause annoyance, resulting in prolonged stress and other health effects. The potential for health impacts depends on acoustic factors (including sound pressure levels and other characteristics of the noise) and non‐acoustic factors (including individual noise sensitivity and attitude to the source).

Infrasound is audible when the sound levels are high enough. The hearing threshold for infrasound is much higher than other frequencies. Infrasound from wind farms is at levels well below the hearing threshold and is therefore inaudible to neighbouring residents.

There is no evidence that sound which is at inaudible levels can have a physiological effect on the human body. This is the case for sound at any frequency, including infrasound.

Box 5: Minnesota Department of Health Conclusions (abridged)

The most common complaint in various studies of wind turbine effects on people is annoyance or an impact on quality of life. Sleeplessness and headache are the most common health complaints and are highly correlated (but not perfectly correlated) with annoyance complaints. Complaints are more likely when turbines are visible or when shadow flicker occurs. Most available evidence suggests that reported health effects are related to audible low frequency noise. Complaints appear to rise with increasing outside noise levels above 35 dB(A). It has been hypothesized that direct activation of the vestibular and autonomic nervous system may be responsible for less common complaints, but evidence is scant.

Low frequency noise from a wind turbine is generally not easily perceived beyond ½ mile. However, if a turbine is subject to aerodynamic modulation because of shear caused by terrain (mountains, trees, buildings) or different wind conditions through the rotor plane, turbine noise may be heard at greater distances.

Unlike low frequency noise, shadow flicker can affect individuals outdoors as well as indoors, and may be noticeable inside any building. Flicker can be eliminated by placement of wind turbines outside of the path of the sun as viewed from areas of concern, or by appropriate setbacks.

Box 6: Chatham-Kent Public Health Unit (Canada) Conclusions

Wind power has been in use around the world for decades with very little human impact. Research occurs when issues create enough interest or concern to compel researchers and scientists into study. Governments fund research but often on a need to know basis. Stakeholders from community groups to turbine manufacturers, rely on expert opinions both for and against wind power, potentially allowing bias to enter the equation.

This document presents the current available white, grey, and published literature on the health effects of wind turbines. Despite copious literature from experts in government, manufacturers of wind turbines, and support groups both for and against wind power, very little scientific evidence exists on the health effects of wind turbines.

This paper concludes and concurs with the original quote from Chatham-Kent's Acting Medical Officer of Health, Dr. David Colby,

"In summary, as long as the Ministry of Environment Guidelines for location criteria of wind farms are followed, it is my opinion that there will be negligible adverse health impacts on Chatham-Kent citizens. Although opposition to wind farms on aesthetic grounds is a legitimate point of view, opposition to wind farms on the basis of potential adverse health consequences is not justified by the evidence."

4.2. KEY FINDINGS OF ACADEMIC ORGANISATIONS AND CONSULTANTS COMMISSIONED BY PUBLIC AGENCIES

Academic researchers and consultants have been commissioned by public health agencies to undertake a detailed review of the scientific evidence and present their key findings to inform policy development and further research in this area. These studies include the aforementioned Adelaide University and Massachusetts reports (see section 3) and the report by Exposure consultant to the Wisconsin Public Service Commission. Their key findings and conclusions are presented below.

Box 7: Adelaide Health Technology Assessment (Adelaide University) Conclusions (abridged)

In summary, the systematic review found no consistent evidence that noise from wind turbines, whether estimated in models or using distance as a proxy, is associated with self-reported human health effects. The quality and quantity of the available evidence was limited.

Wind turbine noise—whether estimated in models or using distance as a proxy—was associated with annoyance, and often associated with sleep disturbance and poorer sleep quality and quality of life. However, there are concerns as to the strength and validity of these reported associations in the available evidence.

Shadow flicker produced by wind turbines was found to be associated with annoyance in one small study, but health effects were not measured. There were no studies identified that investigated the impact on health of the electromagnetic radiation produced by wind turbines.

Box 8: Expert Panel Commissioned by Massachusetts State Government Key Findings (abridged)

Health Impacts of Noise and vibration

1. Most epidemiologic literature on human response to wind turbines relates to self-reported “annoyance,” and this response appears to be a function of some combination of the sound itself, the sight of the turbine, and attitude towards the wind turbine project.

2. There is limited evidence from epidemiologic studies suggesting an association between noise from wind turbines and sleep disruption. In other words, it is possible that noise from some wind turbines can cause sleep disruption.

3. A very loud wind turbine could cause disrupted sleep, particularly in vulnerable populations, at a certain distance, while a very quiet wind turbine would not likely disrupt even the lightest of sleepers at that same distance. But there is not enough evidence to provide particular sound-pressure thresholds at which wind turbines cause sleep disruption. Further study would provide these levels.

4. Whether annoyance from wind turbines leads to sleep issues or stress has not been sufficiently quantified. While not based on evidence of wind turbines, there is evidence that sleep disruption can adversely affect mood, cognitive functioning, and overall sense of health and well-being.

5. There is insufficient evidence that the noise from wind turbines is directly (i.e., independent from an effect on annoyance or sleep) causing health problems or disease.

6. Claims that infrasound from wind turbines directly impacts the vestibular system have not been demonstrated scientifically. Available evidence shows that the infrasound levels near wind turbines cannot impact the vestibular system.

7. There is no evidence for a set of health effects, from exposure to wind turbines, that could be characterized as a "Wind Turbine Syndrome."

8. The strongest epidemiological study suggests that there is not an association between noise from wind turbines and measures of psychological distress or mental health problems. There were two smaller, weaker, studies: one did note an association, one did not. Therefore, we conclude the weight of the evidence suggests no association between noise from wind turbines and measures of psychological distress or mental health problems.

9. None of the limited epidemiological evidence reviewed suggests an association between noise from wind turbines and pain and stiffness, diabetes, high blood pressure, tinnitus, hearing impairment, cardiovascular disease, and headache/migraine.

Health Impacts of Shadow Flicker

1. Scientific evidence suggests that shadow flicker does not pose a risk for eliciting seizures as a result of photic stimulation.

2. There is limited scientific evidence of an association between annoyance from prolonged shadow flicker (exceeding 30 minutes per day) and potential transitory cognitive and physical health effects.

Box 9: Exposure for Wisconsin Public Service Commission

The literature, both scientific and lay, clearly indicates the diversity of concerns regarding the presence of wind turbines near residences and communities. The science of sound is robust and has identified a number of health-related links to high level industrial sound in the workplace. This same science has not identified a causal link between any specific health condition and exposure to the sound patterns generated by wind turbines of the type used today, perhaps because they generate far lower decibel levels than most vocational sources. However, the same science has determined that there is a range of sounds (some would say noise) that is clearly described by some as annoying. The process of being annoyed is a universal response that is not specific to wind turbines.

The non-specificity of annoyance leads to confusion and concern that the peer reviewed published scientific literature has not been able to adequately clarify. It appears that the scientific process of research and discussion before acceptance of new principles, or redefinition of previously accepted principles, has to some extent gotten caught up in rush of the lay media. Jumping from observations and speculation to cause and effect has been the result of this rush. This type of short cut has historically led to misdirection of resources and efforts.

Based on the literature review that was conducted for this white paper, there was not any scientifically peer-reviewed information found demonstrating a link between wind turbines and negative health effects.

5. OVERVIEW OF THE SCIENTIFIC EVIDENCE ON WIND FARMS AND HEALTH

The aim of this section is present an overview of the reviewed literature on wind farms and health. Figure 4 provides an overview of the process used to present the scientific evidence:

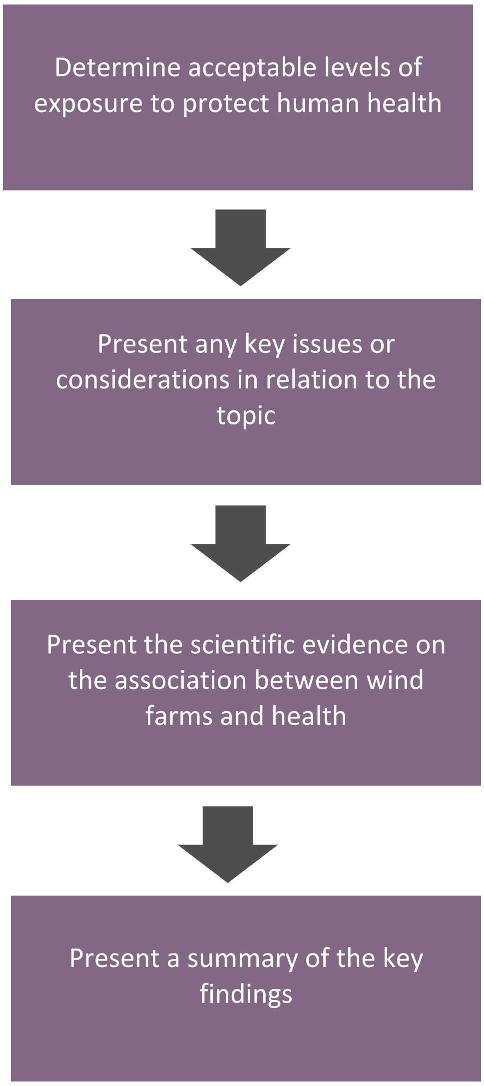

Figure 4: Presentation of the Scientific Evidence

The key findings are presented in tables covering the topics of noise, infrasound, low frequency sound, shadow flicker and electromagnetic radiation (EMR) in the following five tables.

5.1. KEY FINDINGS –WIND FARM NOISE AND HEALTH

Table 2: Key Findings –Wind Farm Noise and Health

KEY FINDINGS - WIND FARM NOISE AND HEALTH	
Acceptable exposure levels	The World Health Organization (WHO) in their publication *Community Noise* (Berglund et al, 1999) outlines the various sources of noise in the community. These include transportation noise, industrial noise and noise associated with residential and entertainment activities. The level of noise is approximated using acoustic measures that consider sound pressure level, frequency, and variations over time (e.g day or night). The mechanism by which audible noise has the ability to affect health depends on the nature of the noise. Based on numerous studies, the WHO outlines that noises that are very loud (greater than 120 - 140 dB) may result in hearing impairment. Noises that are less loud (around 65 – 70dB) but where there is long term exposure may result in a range of cardiovascular effects such as hypertension and heart disease. Exposure to constant noise levels greater than 30 dB at night or where there are variations greater than 10-15 events exceeding 45dB may affect sleep and day time noise greater than 50 – 55dB may result in an annoyance response in the majority of the population. In addition to these guidelines, the WHO notes that noise with a low frequency component may require even lower thresholds and that intermittent noise should consider the sound pressure level as well as the number of noise events (Berglund et al, 1999). The draft National Wind Farm Development Guidelines developed by the Environment Protection and Heritage Council (EPHC) provide a table summarising jurisdictional approaches to noise thresholds. Acceptable wind farm noise levels in Australia fall within the range of 35dBA – 40dBA (EHPC, 2010). However, under some State guidelines, this is increased to 45dBA for participating landholders. Further to this, in many states, a 5dBA penalty applies in wind farm noise levels where noise characteristics such as tonality, amplitude modulation and low frequency noise are detected during the operation of the wind farm (EPHC, 2010).
Key Issues	The main issue associated with audible noise from wind farms appears to be whether noise standards are adequate and if lower criteria are required to protect the community from undesirable health effects. Related to this is the issue of whether residents who live a particular distance from a wind farm are subject to noise exposures that may adversely impact their health. This issue stems from anecdotal evidence in the popular literature and media. The epidemiological studies presented as evidence in this table directly assess whether there is any reliable or valid association between wind farm noise and health. The Victorian Department of Health (2013) observes that noise standards have been developed to protect the majority of people in terms of general amenity. However, unavoidably, a small minority may still experience annoyance at these sound levels. Further to this, Pedersen et al (2007) and Nissenbaum et al (2012) observe that the nature of wind farm noise with its amplitude modulating and impulsive noise characteristics means that it has the potential to be found more annoying to certain people when compared with road or aircraft noise.

KEY FINDINGS - WIND FARM NOISE AND HEALTH	
	The nature of wind farm noise with its varying frequencies raises another issue about the standard acoustic methodology employed to measure sound and whether additional measures are required for low and very low frequencies (Berglund et al, 2009; Minnesota Department of Health, 2009). This is discussed further in Table 3 and 4.
Evidence	The direct evidence regarding negative health impacts associated with audible noise from wind farms is published in a number of peer-reviewed journal articles. The literature reviews by the Adelaide University (Merlin et al, 2013) and Massachusetts researchers (Ellenbogen et al, 2012) include detailed analysis of these articles and their assessments will be drawn upon when presenting this evidence. The three studies from Sweden and the Netherlands were conducted in 2004 and 2007 and are published in a number of articles (Bakker et al, 2012; Pedersen, 2011; Pedersen et al, 2008, Pedersen et al, 2009; Pedersen et al, 2004 and 2007). These studies used a similar questionnaire survey approach that was sent to people living adjacent to wind farms. Acoustic modelling was used to calculate the sound pressure levels for respondents and associations between these noise levels and self-reported physical health effects was the main aim of the studies. The first Swedish study was carried out across five areas and survey results were available for 351 people representing a 68% response rate. The study found some statistically significant associations between outdoor sound pressure levels and annoyance. It also found that the dose relationship for perception and annoyance from wind farm noise was higher than the comparable dose relationship for transportation noise. The study attributed these findings to the aerodynamic noise characteristics of wind turbines as well as perceived visual interference of the wind turbines on rural landscapes. Almost all the residents in the study could see the wind turbines from their properties. However, the study was not conclusive that wind farms caused annoyance because negative attitude to the wind farm were also significant. Ellenbogen et al (2012) in their assessment of the study noted that while the response rate was good, it appeared to correspond with noise levels which indicated that annoyed people were more likely to participate in the survey. Further the pre-existing annoyance levels of respondents were unknown. The second Swedish study was carried out across seven areas and survey results were available for 754 people representing a 57% response rate. The study found some statistically significant associations between perception and annoyance and increasing sound pressure levels. While there were reported sleep difficulties associated with noise annoyance the authors noted that people with sleeping difficulties may appraise noise as more annoying. The authors noted that, noise annoyance was also influenced by how visible the wind farm is to the resident, with residents in hilly areas likely to be less annoyed by the perceived visual intrusion than those in flatter landscapes. The study was not conclusive that there is a clear exposure – effect association between wind farm noise and annoyance because negative attitudes particularly relating to visual perception were also significant.

KEY FINDINGS - WIND FARM NOISE AND HEALTH	
	Ellenbogen et al (2012) in their assessment of the study noted that while this study appeared more rigorous than the earlier Swedish study in terms of the selection process and masking of survey intent, the non-response levels do not adequately address selection bias and results may be inflated. Further to this, they observe that the association between noise and annoyance was weakened once adjustments were included for negative attitudes to the wind farms; suggesting then that the pathway by which noise causes annoyance may be as follows: noise→ negative attitude → annoyance. The Dutch study was carried out across three areas and survey results were available for 725 people representing a 37% response rate. The study found that there was no direct association between wind farm noise and sleeplessness or psychological distress, however some respondents living in the vicinity of wind turbines were annoyed by the sound and that the level of annoyance corresponded to the level of exposure. The study found however that this annoyance may depend on sound pressure levels as well as psychological factors. Among respondents that benefitted economically from the wind farm and who are exposed to the highest noise levels, the portion of people annoyed was much lower. Similarly, there were lower levels of annoyance reported by people who could not see a wind turbine. The study was not conclusive that levels of wind farm noise are directly associated with annoyance because negative attitudes to the wind farm were also significant factors. Ellenbogen et al (2012) in their assessment of the study noted that the cross-sectional design and low response rate mean that selection bias may have inflated the data. Further to this, the association between noise and annoyance was not consistent enough to determine if it occurred independent of seeing a wind turbine. Pedersen (2011) used the data from Swedish and Dutch cross-sectional studies to re-analyse whether there are any statistically significant health outcome (such as chronic disease, diabetes, high blood pressure, tinnitus, head aches) associated with increasing sound pressure levels. The study found that there were no consistent associations between wind farms and chronic health conditions. The only consistent association was with annoyance; however, this was not always related to noise levels and was influenced by a range of factors including attitude to the development. In their interpretation of the comparative results, Merlin et al (2013) note there was no statistically significant health effect reported across all of the three studies and even where adjustments were made for age, gender and economic benefit, health outcomes did not appear to vary with increased sound pressure levels or distance from wind turbine. The studies conducted by Shepherd et al (2011), Krogh et al (2011) and Nissenbaum et al (2012) were conducted in New Zealand, Canada and the US respectively and used cross-sectional surveys to assess whether respondents living close to wind turbines had any more physical health complaints than people living further away. Acoustic modelling was not used and instead distance from the wind turbine was used as the proxy for noise exposure. The US study was carried out in Maine and compared populations living close to the wind farm (375 – 1400m) and further away from the same wind farm (3.3 – 6.6 km). The survey used

KEY FINDINGS - WIND FARM NOISE AND HEALTH	
	validated instruments for assessing mental and physical health and sleeplessness. The response rate was small at 38 for adjacent respondents and 41 for respondents further away. The study found that some people within the 1.4km distance experienced worse sleep; were sleepier during the day; and had worse mental health when compared to some people living further away. The study concluded that noise from wind farms results in similar health impacts and this may be due to impulsive nature of the noise due to its major low frequency component. Merlin et al (2013) in their assessment of the study note that while the study has used validated questionnaires, the study locations were chosen specifically because health effects were anecdotally reported in those areas which may result in biased selection. Further to this, the aim of the study was not masked meaning that those with health complaints would more likely respond. These limitations with the study were also highlighted by the study author. The New Zealand study compared two demographically matched areas that only differed in that one was located within two km from a wind farm. Survey results were available 54 residents who lived adjacent to the wind turbine and 250 residents who lived eight km away from any wind farm region. The intent of the study was masked by framing it in terms of general neighbourhood factors and a validated questionnaire process based on WHO quality of life indicators was used. The study found that exposure to wind farms is linked to a degraded quality of life in terms of physical, environmental and general factors. The study also observed that lower sleep satisfaction, noise annoyance and perceived degraded amenity all contributed to the findings. Merlin et al (2013) in their assessment of the study noted that while the use of validated questionnaires and masking of the study was good, the study was unable to report any statistically significant associations between distance from wind turbine and self-reported health effects. Therefore the evidence presented could not provide a reliable or valid association between exposure level and adverse health. The final study was undertaken and involved a survey being sent to all residents living in five areas in Canada where adverse health effects associated with wind farms had been anecdotally reported. The number of survey participants was 109 though six participants were removed as not meeting the criteria (due to underage or distance from wind farm). The study found that 72% of participants reported increased symptoms of anxiety, stress, or depression since the start of the wind farm project and that the most common adverse health outcomes reported included sleep disturbance, excessive tiredness and headaches. The study authors noted the selection bias of the results and that it was undertaken to inform the need for large-scale epidemiological studies and additional setbacks where required. Merlin et al (2013) in their assessment of the study noted that the study does not present a statistically significant difference between the reported health outcomes (e.g altered health, headaches, hearing problems etc) and distance from wind farm and also the selection bias of the survey design. Therefore the evidence presented could not provide a reliable or valid association that exposure to wind farms caused annoyance.

KEY FINDINGS - WIND FARM NOISE AND HEALTH	
Key Finding	In the reviewed literature, the health impacts associated with audible noise from wind farms has attracted the most peer reviewed epidemiological studies in the field, noting that this is still a limited number (six studies published in 11 articles). The overall quality of these epidemiological studies on wind farms and health is rated as low due to methodological issues such as the selection bias of respondents and self-reporting of health impacts. The key finding from the reviewed literature is that there is no scientific evidence that exposure to wind farm noise can cause adverse health impacts. While there is evidence that some people living in proximity to a wind farm may experience annoyance, there is no consistent evidence that wind farm noise directly causes annoyance, and it may be that these people's annoyance stems from a number of factors including negative attitudes to the project.

5.2. KEY FINDINGS –WIND FARM INFRASOUND AND HEALTH

Table 3: Key Findings –Wind Farm Infrasound and Health

KEY FINDINGS –WIND FARM INFRASOUND AND HEALTH	
Acceptable exposure levels	The Victorian Department of Health (2013) and Rideout et al (2013) observe that infrasound is generated by a number of natural sources including coastlines, wind and waterfalls. It is also generated by a number of engineering sources such as air conditioners, vehicles and wind farms. The authors observe that infrasound like low frequency sound has been observed to have a subjective quality and some people are more sensitive to the lower frequencies than others. The mechanism by which infrasound has the ability to affect health depends on the level of exposure. According to Ellenbogen et al (2012) high level doses can cause direct adverse health effects on the cardiovascular, brain and respiratory system. This evidence has been drawn from animal studies and the findings reflect the acute effects of short-term, high doses. Leventhall (2006) similarly observes that high levels of sound (165 dB at 2 Hz) can cause aural pain in the middle ear system. The Minnesota Department of Health in their publication *Public Health Impacts of Wind Farms* (2009) also find that the vestibular system (physical balance and equilibrium) is sensitive to frequencies at 100 Hz and even as low as 12.5 Hz. However, intensive activation of the system is required to result in sensations such as vertigo, nausea, vomiting and cardiac and respiratory changes. At lower levels of exposure, the reviewed literature indicates that infrasound can result in annoyance due to the feeling of pressure on the ear drum. Further to this, small changes or fluctuations in this frequency can increase the annoyance markedly. (Rideout et al 2010; Victorian Department of Health, 2013; Evans et al, 2013). At imperceptible levels of infrasound, it is generally accepted that no physiological effects occur (Leventhall, 2006). Studies have been conducted by inner ear experts to determine whether the hair cells of the cochlear can detect airborne infrasonic sound resulting in health effects such as

KEY FINDINGS –WIND FARM INFRASOUND AND HEALTH	
	dizziness, nausea and headaches. However, these studies and other cited in the field have not found any conclusive associations (Ellenbogen et al, 2012; Evans et al, 2013). Leventhall (2006) observes that the misconception that infrasound can be felt and not heard is not valid because the sound levels for vibrations to be felt in the body are within the audible threshold. Hearing thresholds for infrasound become audible when sound pressure levels are high (Victorian Department of Health, 2013). The internationally accepted threshold for exposure to infrasound set by Denmark is 85dBA which is just below the average threshold of hearing (Rideout et al, 2010; Victorian Department of Health, 2013). Currently, no State or Territory Government in Australia requires an assessment of infrasound as part of noise assessments for wind farms.
Key Issues	Infrasound and low frequency sound associated with wind farms has attracted a number of studies in the non-peer reviewed literature which support an association between direct health impacts and wind farms. References to publications by authors such as Nina Pierpont can be found in the reviewed literature (Ellenbogen et al, 2012; Minnesota Department of Health, 2009; Leventhall, 2006; Roberts et al, 2009). Using terms such as wind turbine syndrome to collectively describe a number of chronic health conditions, the authors have associated adverse health effects with sound and vibration at infrasonic and low level frequencies. The peer reviewed literature and publications by public health agencies have discredited these studies due to their poor quality and lack of scientific review (Ellenbogen et al, 2012Chatham-Kent Public Health Unit, 2008). However, according to the reviewed literature, these studies and the controversy that surrounds them have contributed to some concern about health effects in the popular media and amongst the community (Roberts et al, 2009). The other issue associated with infrasound is whether wind farms emit levels that are within the range to cause annoyance and whether the noise assessment methodologies currently adopted are adequate to measure low levels of infrasound (Berglund et al, 2009; Minnesota Department of Health, 2009). .
Evidence	The direct evidence in terms of epidemiological studies on wind farm infrasound and health is limited. The literature review conducted by Merlin et al 2013 for example did not identify any epidemiological studies that met their selection criteria for systematic review and reported on infrasound and low-frequency noise exposures from wind turbines. The literature review conducted by Ellenbogen et al 2012 identified a number of animal studies for infrasound exposure at acute or high levels, but was unable to locate any animal studies that were comparable to the exposures of wind turbines. Based on the reviewed literature, it seems that most of the peer reviewed literature on this subject has been carried out by acoustic engineers. Research conducted by Jakobsen (2005) has found that whether a wind turbine operates as an upwind or downwind turbine can influence the level of infrasound experienced. Jakobsen reviewed a range of modern wind turbine designs and measured their infrasound levels. The study found that rotors of contemporary design that are placed upwind produce very low levels

KEY FINDINGS –WIND FARM INFRASOUND AND HEALTH	
	of infrasound. However, downwind rotors generate considerably higher infrasound levels which may exceed noise thresholds up to several hundred metres from the turbine. Jakobsen concludes that modern up-wind wind turbines typically exhibit infrasound at between 50 – 70dBG which is below the audibility threshold. The results published by Jakobsen have been confirmed through recent Australian studies undertaken by Evans et al (2013) and Turnbull et al (2012). The first study was conducted by the South Australian Environment Protection Agency in conjunction with noise consultants Resonance Acoustics aimed to determine the levels of infrasound which people are exposed to in a number of environments. Indoor and outdoor infrasound was measured over a period of days (up to seven) inside 11 buildings in urban and rural environments. This included seven locations in urban areas, two in rural areas adjacent to wind farms and two locations in rural areas approximately 1.5 km from wind farms. The study found that G-weighted infrasound levels at rural locations both adjacent to and at a distance from wind farms were significantly below the threshold of 85dBG and were no higher than infrasound levels measured at urban locations. The study concluded that human activity and traffic appeared to be the primary source of infrasound in urban locations, with local wind conditions the primary source in rural conditions. The second Australia study was also undertaken in South Australia. The aim was to measure the levels of infrasound at a range of distances for two wind farms (Clements Gap Wind Farm and Cape Bridgewater Wind Farm) and compare the result with infrasound measurements taken near natural sources such as beaches and engineered sources such as a power station and activity within the city of Adelaide. At Clements Gap Win Farm, infrasound was measured at distances of 85 m, 185 m and 360 m from the base of the wind turbine in the down wind direction. At the Clements Bridgewater Wind Farm the infrasound was measured at distances of 100 m and 200 m from the base of the wind turbine in a downwind direction. Other measurement points were 250 m inland from a coastal cliff, 8 km inland from the coast, 350 m from a power station and 70 m from a major road in the city. The study found that measures of infrasound from all the locations were well below the 85dBG threshold of audibility. It was also found that at 100 m from the wind farm the turbine may be a significant contributor of infrasound. However at a distance of 200 m local wind conditions and background noise were at least as significant.
Key Finding	In the reviewed literature, the health impacts associated with infrasound from wind farms has not attracted any peer reviewed epidemiological studies. A number of peer reviewed acoustic studies have been undertaken however. The key finding from the reviewed literature is that there is no scientific evidence that exposure to wind farm infrasound can cause adverse health impacts. Levels of exposure to wind farm infrasound have consistently been found to be below the 85dBG threshold of human perception. There is no evidence of physiological effects from infrasound that is below the level of audibility.

KEY FINDINGS –WIND FARM INFRASOUND AND HEALTH	
	The infrasound emitted by wind farms has been found to be comparable to a number of other sources including coastlines, urban areas and other industrial processes.

5.3. KEY FINDINGS - WIND FARM LOW FREQUENCY NOISE AND HEALTH

Table 4: Key Findings - Wind Farm Low Frequency Noise and Health

KEY FINDINGS –WIND FARM LOW FREQUENCY NOISE AND HEALTH	
Acceptable exposure levels	Sources of low frequency sound have been identified in the reviewed literature to include buses, trains and some aircraft as well as heating, cooling or ventilation of buildings (Roberts et al, 2009). Low frequency sound is made up of long waves which have low pitch and attenuates in intensity (loudness) over longer distances. It can therefore travel through structural mediums such as walls and windows more easily than shorter and higher frequency waves (Merlin et al, 2013; Roberts et al, 2009). The Victorian Department of Health (2013) states that particular characteristics of low frequency sound mean that a sound that is inaudible to one person may be audible and annoying to others, and that annoyance also increases more rapidly for slight changes in this frequency range. Berglund in the article 'Effects of Low Frequency Noise' (1996) provides a detailed assessment of the various mechanisms by which low frequency noise can affect human health. She observes that the threshold of aural pain is approximately 135 dB for sound energy around 50 Hz with a steady increase in threshold to around 155 dB at 5 Hz. At these high intense levels a number non-auditory effects can also be observed on the respiratory and vestibular system. Leventhall (2006) notes that high levels of low frequency sound can excite body vibrations. The most prominent body response being a chest vibration experienced at 80 dB in the region of 50 – 80 Hz. Berglund (1996) states that annoyance is the most frequently reported effect of low frequency noise. Even through the noise may be within standard guidelines, the low frequency characteristics may increase annoyance significantly. The WHO in their commissioned publication *Community Noise* (Berglund et al, 1999) note that when prominent low frequency components are present, acoustic measures based on an A-weighting are inappropriate and that a better assessment would be to use the difference between an A and C weighting. The low frequency sound from wind farms is primarily generated by the in-flow turbulence on the wind turbine blades (Bolin et al, 2010). The Victorian Department of Health (2013) state that the dominant frequencies produced by wind farms are in the 200 – 1,000 Hz range and the mid-high level frequency intermittent 'swish' is the main sound heard approximately 300 m from a wind turbine (Victorian Department of Health, 2013).

KEY FINDINGS –WIND FARM LOW FREQUENCY NOISE AND HEALTH	
	Currently, no State or Territory Government in Australia requires an assessment of infrasound or low frequency sound as part of noise assessments for wind farms. However, the Tasmanian Government *Noise Measurement Procedures Manual 2004* does include a reference to NZ 6808 and requires a penalty of 5dB where low frequency sound is detected post-construction. The draft National Guidelines (EPHC, 2010) recommend an assessment of low frequency sound where any complaints are received. They recommend a difference between A-weighted and C-weighted levels of not more than 20dB and a 5dBA penalty where low frequency noise is measured post-construction**.** As a rule of thumb, for exposure levels from low frequency sound, Bolin et al (2011) and Ellenborg et al, 2012 have suggested that further investigations should be conducted if the measured difference is greater than 15dB and the WHO in their 1999 publication recommends further assessment if the difference is greater than 10dB (Berglund et al, 1999).
Key Issues	As highlighted in the Table above, in the non-peer reviewed literature there have been studies published that have drawn an association between infrasound and low frequency sound from wind farms and direct health effects referred to as “wind turbine syndrome” (insomnia, tinnitus, dizziness, nausea and panic attacks). These and related studies have contributed to media and community commentary and concern about the health impacts of wind farms (Roberts et al, 2009). The other issue identified in the reviewed literature is whether low frequency sound from modern wind farms is audible at distances where people are living and whether it does contribute to annoyance in exposed populations. Related to this is whether low frequency noise is adequately measured and assessed using the standard dBA noise approach (Berglund et al, 2009; Minnesota Department of Health, 2009).
Evidence	Similar to infrasound, the direct epidemiological evidence on wind farm flow frequency sound and health is limited. The literature review conducted by Merlin et al 2013 for example did not identify any epidemiological studies that met their selection criteria for systematic review and reported on infrasound and low-frequency noise exposures from wind turbines. Bolin et al (2011) in their review of studies conducted by Pedersen and others agree that wind turbine noise is more annoying than road traffic noise at the equivalent noise level of 40dB. However, in their review of the literature they could find no indication that it is linked to infrasound or low frequency noise from wind turbines. The study concludes that it is more likely associated with the lower background noise in rural areas, the ‘swishing’ ‘swooshing’ and ‘pulsating’ of the amplitude modulated trailing edge noise of mid-high frequency range, and perceived visual intrusion of the wind farm on the landscape (Bolin et al, 2011). This conclusion is supported by the NHMRC who observe that lower frequency sound is primarily produced by the mechanical elements of the turbine with the ‘swooshing’ produced by the aerodynamic elements in the mid-high frequency range (NHMRC, 2014). Therefore it may also be less of a concern with the modern upwind wind farm design.

KEY FINDINGS –WIND FARM LOW FREQUENCY NOISE AND HEALTH	
	There are a number of acoustic studies that have been published in peer reviewed journal articles in relation to low frequency noise from wind farms. Bolin et al, 2011 cites a study conducted by O'Neal et al in 2011 which compared indoor and outdoor low frequency noise and infrasound at two wind farms one 30 x 1.5MW turbines and the other 15 x 2.3 MW turbines (location not cited). The study found that the measured levels from low frequency noise and infrasound complied with relevant national guidelines at a distance of 305m or more from the wind turbine. Bolin et al (2011) note that low frequency noise may occur in rare cases and that larger wind turbines may produce more low frequency sound than smaller ones, though this is still expected to be below annoyance levels. However, as identified in the evidence presented in Table 2, the effect of social and environmental factors is a key consideration where a person's individual noise sensitivity and attitude to the wind farm can affect their annoyance.
Key Finding	In the reviewed literature, the health impacts associated with low frequency sound from wind farms has not attracted any peer reviewed epidemiological studies. A number of peer reviewed and public health acoustic studies have been undertaken however. The key finding of the reviewed literature is that there is no scientific evidence that exposure to wind farm low frequency noise causes adverse health impacts. The amplitude modulating characteristics of wind farm noise (also referred to as 'swooshing') that have anecdotally been associated with annoyance are in the mid-high frequency range and would be measured through standard dBA noise assessments.

5.4. KEY FINDINGS - WIND FARMSHADOW FLICKER AND HEALTH

Table 5: Key Findings - Wind Farm Shadow Flicker and Health

KEY FINDINGS –WIND FARM SHADOW FLICKER AND HEALTH	
Acceptable exposure levels	The reviewed literature suggests that shadow flicker occurs when the moving blades of a wind turbine cause intermittent changes in light and shadow. Shadow flicker is determined by a number of factors including height and position of the wind turbine, time of day, and weather conditions (Harding et al, 2008, Ellenbogen et al, 2012, Merlin et al, 2013, Rideout et al, 2013). The mechanism by which shadow flicker has the ability to affect health has been described in the reviewed literature in terms of short and long term exposure effects. Merlin et al (2012) reviewed a number of studies which investigates frequency thresholds and seizure risk from shadow flicker relating to flickering sunlight, rotating helicopter blades and flicker rates of television. Citing the Institute of Electrical and Electronics Engineers (2013) the authors note that a few seconds of exposure can result in epileptic seizures in 3% of people with photosensitive epilepsy and can occur within a range of 3 – 70Hz and long-termer exposure from invisible

KEY FINDINGS –WIND FARM SHADOW FLICKER AND HEALTH	
	flicker at <165 Hz can result in malaise, headaches and impaired visual performance. In terms of long term exposure to shadow flicker, Ellenbogen et al (2012) were only able to identify one Government study undertaken in Germany which involved a control group being exposed to projector generated shadow flicker for more than 30 minutes. The study found a range of both physical and cognitive effects from the exposure scenario. However the laboratory conditions of this study were different to the environmental stimuli of wind farms. In the context of wind farms, Merlin et al (2013) observe that these exposure levels are generally higher than the levels emitted from modern wind farms which are expected to be in the range of ≤1 Hz. This is confirmed by Ellenbogen et al, 2012 who state that shadow flicker frequencies from wind turbines are between 0.3 and 1 Hz which is outside the thresholds according to the US National Resource Council and Epilepsy Foundation. The key risk of shadow flicker as noted by Merlin et al and the EPHC draft guidelines (2010) is the potential to annoy some individuals. As stated by the EPHC, shadow flicker can extend many kilometres from a wind turbine however the shadow loses intensity with distance. People have different levels of sensitivity to shadow flicker and therefore guidelines are set above the “minimum theoretically detectable threshold”. The internationally accepted guidelines for shadow flicker are set by Germany at 30 hours per year and 30 minutes per day for modelled shadow flicker and eight hours per year for actual shadow flicker based on astronomical and clear sky calculations (Ellenbogen et al, 2012 and EPHC, 2009). This is the generally accepted standard in Australia (EPHC, 2010) and shadow flicker assessments are undertaken as part of standard planning and approval processes.
Key Issues	Shadow flicker has attracted limited interest in the reviewed literature on wind farms and health. The main issues regarding shadow flicker appear to be ensuring that shadow flicker frequencies of wind farms do not approach the photosensitive range and that annoyance and nuisance factors are managed for residents and distracting effects on drivers (Rideout et al, 2013).
Evidence	The direct evidence regarding shadow flicker from wind farms is limited and mainly relates to modelled seizure risk from wind farms and reviews of the literature. The evidence discussed in these studies is presented below. A study by Harding et al, 2008 observed that photosensitive epilepsy occurs in approximately 1 / 4,000 of the population and persists for life for 75% of patients. Sunlight is a precipitant of photosensitive seizures. The study explored the characteristics of wind turbine flashing that may induce seizures. The study found that modern wind turbines generally rotate at between 30-60 revolutions per minute (rpm). These three bladed turbines operate at a constant speed and produce a flicker rate of approximately 3 Hz which is outside the photosensitive range. However, smaller wind turbines have a variable speed range of between 30 – 300 rpm, some have more than three blades and their flicker is within the range for which seizures may occur.

KEY FINDINGS –WIND FARM SHADOW FLICKER AND HEALTH	
	Harding et al used a relationship between the angle of the stimulated areas of the cortex in photosensitive individuals and the wind turbine blade to estimate possible distances at which shadow flicker is likely to be seizure provoking (for a turbine blade that is 1m in diametre this is likely to be 1.14km). The study concluded that at 3Hz or less, the cumulative risk of inducing a seizure would be about 1.7 per 100,000 and recommended that the rotation speeds of the blades should be kept to a minimum and not exceed 60 rpm. Further to this, that layout of wind farms can be modified to comply with recommended guidelines. A companion study by Smedley et al (2010) resulted in similar conclusions. The study found that large wind turbines were unlikely to rotate at speeds that would induce seizures. Further investigating the relationship between angle of the eye and the exposure to shadow flicker, the study found that there appeared to be no risk for seizures unless a person with photosensitive epilepsy was closer than 1.2 times the total turbine height which could potentially result in frequencies greater than 5 Hz. According to the literature reviews undertaken by the AHAT and Massachusetts researchers, shadow flicker is primarily an issue of annoyance. While there are no peer reviewed scientific articles that explore this association in detail, it is generally accepted that exposure of people to shadow flicker can increase annoyance levels particularly where they do not benefit economically or receive electricity from the wind farm and whose land is adjacent to where the turbines are located (Ellenbogen et al, 2012, Rideout et al, 2013).
Key Finding	In the reviewed literature, the health impacts associated with shadow flicker from wind farms has not attracted any peer reviewed epidemiological studies. The key finding of the reviewed literature is that there is no scientific evidence that wind farm shadow flicker can cause adverse health impacts. There is negligible risk of seizure from modern three bladed wind turbines which rotate at a speed that is below the level to elicit a seizure response in photosensitive individuals. International guidelines for layout and design of wind turbines are in place to reduce the potential for shadow flicker to cause annoyance.

5.5. KEY FINDINGS - WIND FARM EMR AND HEALTH

Table 6: Key Findings - Wind Farm EMR and Health

KEY FINDINGS –WIND FARM EMR AND HEALTH	
Acceptable exposure levels	Electromagnetic magnetic fields (EMF) are created by a number of appliances such as microwaves, the television and computers. In the context of wind farms it is created by grid connection lines, underground network cabling, electrical transformers and turbine generators (Rideout et al, 2013).

KEY FINDINGS –WIND FARM EMR AND HEALTH	
	The mechanism by which exposure to electromagnetic fields has the ability to affect health depends on the level of exposure. The WHO (2012) examined EMF from a range of source including high voltage power lines, mobile phone towers and a range of electric appliances in the household for magnetic fields (measured as µT) and electric fields (V/m). According to the WHO (2012) the guideline limit value for electric fields is 5kV/m. Directly under high voltage power lines this can be as high as 10kV/m though at distance of 50 – 100m this would decrease to 0.2 µT. They also noted that the acceptable threshold for household appliances is 100 µT at 50 Hz at a distance of 30 cm. A vacuum cleaner may be 200-800 µT at 3cm from the source but this decreases to 2 – 8 µT at 30 cm. Similarly, a microwave oven is 73-200 µT at 3cm, but 2 – 20 µT at 30cm. According to the WHO, magnetic field strength rapidly decreases as distance from the source increases. In their review of the parallel and mechanistic epidemiological literature, Merlin et al (2013) identified that some studies have explored the potential link between electromagnetic fields and childhood leukaemia at low levels of exposures of 0.4 µT although the results of these studies have been inconclusive. An Australian study undertaken by Karipidis in 2005 and cited by Merlin et al examined the magnetic fields in a number of selected appliances measured at a 30 cm separation. The report found that when averaged these appliances do not exceed the 0.4 µT threshold though the levels may fall within the range on a day to day basis. Another Australian study cited by Merlin et al (Armstrong et al, 2007) examined the association between breast cancer experienced by 10 women working in a television studio in Brisbane. However the results did not find any conclusive links with electromagnetic fields. Wind farms are expected to generate EMR at very low levels comparable to household appliances however there were no reviewed studies that specifically measured EMR from wind farms (Merlin et al 2013; Rideout et al, 2013). There is a reference to an acoustic study conducted by Windrush Energy and cited by the NHMRC which showed that levels of EMR emitted by wind farms were comparable to the level emitted by a vacuum cleaner; however as this was not peer reviewed it has not been reviewed in detail in this report. The reviewed literature did not identify any standards or guidelines for EMR from wind farms. It is useful to note that the potential for EML to disturb radio communications is assessed as part of the planning and approval process for wind farms in Australia (refer EHPC, 2010).
Key Issues	EMR has attracted limited interest in the peer reviewed literature on wind farms and health. The main issue regarding EMR is determining whether wind farms are likely to emit significant levels of EMR and whether these are within acceptable thresholds.
Evidence	The direct evidence regarding direct health impacts from EMR is very limited. Merlin et al (2013) could not identify any epidemiological studies that examined health impacts in relation to EMR from wind farms. Further to this, the literature reviews conducted by Ellenbogen et al (2012) and Knopper et al (2011) have not considered EMR as a health issue in their reviews. Rideout et al (2013) provide an assessment of the levels of electromagnetic fields likely to be

KEY FINDINGS –WIND FARM EMR AND HEALTH	
	created by wind farms. They note that the grid connections lines of wind farms are similar to other power lines and are expected to generate electromagnetic fields comparable to household appliances. They note that turbine generators are located 60-100 m above the ground which would unlikely result in any electromagnetic fields on the ground. Similarly the underground cables that connect turbines would not create significant levels of electromagnetic fields at the surface. The highest source of electromagnetic field would be created by the transformers, but even these were considered by the authors to be insignificant.
Key Finding	In the reviewed literature, the health impacts associated with EMR from wind farms has not attracted any peer reviewed epidemiological studies. The key finding of the reviewed literature is that there is no scientific evidence that wind farm EMR can cause adverse health impacts. There is anecdotal evidence that wind farms generate EMR at the same level as household appliances but no peer reviewed studies to confirm this is the case.

6. RELEVANCE OF EVIDENCE TO COOPERS GAP WIND FARM PROJECT

The aim of this section is to provide a comparative assessment of the similarities and differences between the sites and wind farm projects presented as evidence in Section 5 and the proposed Coopers Gap Wind Farm Project.

The process for undertaking this assessment involves reviewing the 13 studies that were cited as scientific evidence in the tables on noise, shadow flicker and EMR in Section 5 and drawing out site and wind farm characteristics where available (e.g size of wind farm, distance of residents from turbines, and topography).

Table 7 on the following page presents the results of this comparative exercise.

As shown in the tables, the level of detail on the study sites, wind farm capacity and design, and distance of residents from the turbines are limited. However, the general view that can be gained from the comparative table is that the studies have all examined modern industrial wind farm of greater than 500kW capacity mostly located in rural landscapes. Comparatively, the proposed Coopers Gap Wind Farm Project may be considered a larger sized project surrounded by a very small population. The landscape is generally of undulating to hilly rural character typical of the region with widespread clearing of eucalypt woodland/forest for agricultural purposes. Overall, it would be likely that the findings of the evidence tables would be relevant to the Coopers Gap Wind Farm project.

It should also be noted that AGL has undertaken a number of assessments for the proposed Coopers Gap Wind Farm project covering the issues of turbine design, noise, infrasound, low frequency noise and shadow flicker and electromagnetic interference. These assessments have confirmed that the proposed wind farm would operate within recommended Australian guidelines for these factors. Further to this, the proposed wind turbines would be of modern wind turbine design with three blades, low reflective blades and upwind design. The assessments are published in the Revised Assessment Report for the Project.

Table 7: Comparative Assessment of Studied Sites and the Coopers Gap Wind Farm Project

No	Reference	Location of wind farm	Topography	Construction Date	Turbine number and capacity	Turbine hub height and rotor diameter	Distance of residents from wind turbine and dBA of contour	Total number of residences or people in study area
Coopers Gap Wind Farm Project								
	AGL Coopers Gap Revised Assessment Report, 2014	Near Cooranga North in Central Southern QLD	Rural		Up to 139 turbines of maximum 2 – 4 MW	Max of 100m height and 126 m diametre	Approx 800m involved landowners (45dBA) and approx 1000m-1300m non-involved landowners (40 dBA) – dependent on topography	10 involved landholders with turbines on property. Approx 50-100 in nearby localities
Noise								
1	Pedersen et al 2004	Various sites across Sweden	Seven areas of different terrain and population density	Varied	Each turbine >500kW	unknown	Unknown >30 dBA for populations <500 and >35dBA for populations >500	1309 households
2	Pedersen et al 2007	Various sites across southern Sweden	Five areas of flat largely agricultural land	Varied	14/16 turbines were >600-650kW. 13/16 turbines designed by WindWorld	Average height 47 m – 50 m	unknown > 30dBA	627 households

No	Reference	Location of wind farm	Topography	Construction Date	Turbine number and capacity	Turbine hub height and rotor diameter	Distance of residents from wind turbine and dBA of contour	Total number of residences or people in study area
3	Bakker et al 2012	Various sites across Netherlands	Three areas: rural area with no major road, rural area with major road within 500m and more densely populated built up area	Varied	Each turbine >500kW and within 500m of another turbine	Unknown	2.5 km or less At least 50 people in each sound exposure class: <30dBA, 30 – 35, 36 – 40, 41-45, >45dBA)	1,948 households
4	Shepherd et al 2011	Makara Valley, 10 km west of Wellington in NZ	Hilly terrain in coastal area	2009	66 turbines	62 m height and 82 m diameter	2 km or less 20 dBA – 50 dBA depending on weather conditions	56 households
5	Nissenbaum et al 2012	Mars Hill and Vinalhaven (now called Four Islands) in Maine, US	Mars Hill – mountainous Vinalhaven - flat	Mars Hill – 2006 Vinalhaven - 2009	Mars Hill – 28 turbines of 1.5MW Vinalhaven – 3 turbines of 1.5MW each	Mars Hill – 80 m in height Vinalhaven – 118.5 m height	1.5 km	Mars Hill - 33 adults Vinalhaven - 32 adults

No	Reference	Location of wind farm	Topography	Construction Date	Turbine number and capacity	Turbine hub height and rotor diameter	Distance of residents from wind turbine and dBA of contour	Total number of residences or people in study area
6	Krogh et al 2011	Seven sites in Ontario Canada (three detailed here)	Melancthon – flat Kingsbridge – flat near lake Kruger Energy Port Alma – flat near lake Erie	Melancthon – 2008 Kingsbridge – 2006 Kruger Energy Port Alma – 2008	Melancthon – 133 turbines of around 1.5MW Kingsbridge – 22 turbines of about 1.6MW Kruger Energy Port Alma – 44 turbines of 2.MW	Melancthon – 80 m in height Kingsbridge – 78 m in height Kruger Energy Port Alma – 80 m height, 93 m diameter	Unknown	Unknown
Infrasound								
7	Evans et al 2013	Two sites in South Australia: near Hallet (Bluff Hill) and near Crystal Brook (Clements Gap)	Rural	Bluff Hill – 2012 Clements Gap – 2010	Bluff Hill Wind Farm: 24 turbines of 2.1MW Clements Gap Wind Farm: 27 turbines of 2.1MW	Bluff Hill – 107 m (to blade tip) Clements Gap– 79 m height, 88 m rotor diametre	Bluff Hill: 1.5 km. Outdoor infrasound: 40 – 60dBG Clements Gap: 1.4 km. Outdoor infrasound:50 – 75dBG	Unknown (measures taken at one residence)

No	Reference	Location of wind farm	Topography	Construction Date	Turbine number and capacity	Turbine hub height and rotor diameter	Distance of residents from wind turbine and dBA of contour	Total number of residences or people in study area
8	Turnbull et al 2012	Two sites: mid North South Australia and South-West Victoria	Rural	Clements Gap – 2010	Clements Gap Wind Farm: 27 turbines of 2.1MW Cape Bridgewater Wind Farm: 29 turbines of 2.0MW	Clements Gap– 79 m height, 88 m rotor diametre	Clements Gap: 85m, 185m and 360m. 61 – 72dBG (infrasound) Cape Bridgewater: 100m and 200m. 63 – 66dBG (infrasound)	Unknown
Low Frequency Noise								
9	Jakobsen 2005	Unknown	Unknown	Unknown	Turbines ranging from 50kW to 4.2MW (average = contemporary wind farm size)	Unknown	Distances ranging from 80m to 2.1 km (average = 100m) Infrasound Measurements ranging from 56dBG – 107dBG (average = 70dBG	N/A
10	O’Neal et al cited in Bolin et al 2011	Unknown	Unknown	Unknown	Site 1: 30 turbines of 1.5MW Site 2: 15 turbines of 2.3MW	Unknown	Distances of 305m complied with relevant guidelines for infrasound and low frequency noise	Unknown

No	Reference	Location of wind farm	Topography	Construction Date	Turbine number and capacity	Turbine hub height and rotor diameter	Distance of residents from wind turbine and dBA of contour	Total number of residences or people in study area
Shadow Flicker								
11	Harding et al 2008	N/A	N/A	N/A	Large wind turbine 3 blades rotating at 40-60rpm	Unknown	N/A	N/A
12	Smedley et al 2009	N/A	N/A	N/A	Large wind turbine 2MW turbine	Blade width 2m	N/A	N/A
EMR								
13	Rideout et al, 2013	N/A	Unknown	N/A	Unknown	60-100m height	Unknown	N/A

7. SUMMARY AND CONCLUSIONS

This report has provided an overview of the peer reviewed scientific evidence on wind farms and health as it relates to noise, shadow flicker and electromagnetic radiation. References were identified through a selection process that resulted in a list of 47 references comprising peer reviewed journal articles and publications by public health agencies. The recent NHMRC publications and systematic and comprehensive literature review undertaken by the Adelaide Technology Assessment Team from Adelaide University and the independent panel commissioned by the Massachusetts Government were key source references for this report.

The general consensus of public health agencies and academic researchers identified in the reviewed literature is there is no scientific evidence of an association between exposure to wind farms and adverse health impacts. This applies to noise, low frequency noise, infrasound, shadow flicker and electromagnetic radiation.

While this report has endeavoured to present an overview of the best available evidence, it has found that the direct evidence represented by epidemiological studies of wind farms and health are in general of poor quality and limited scope. These studies are primarily related to noise, are limited in number, and use cross-sectional survey design and limited masking of study intent which may result in bias and inflation of results. A number of background studies have been used in the reviewed literature and within this report to support the key findings, particularly in areas where there is limited direct evidence.

The summary of the key findings from the reviewed literature on wind farms and health is presented below. A desk-based comparison of the wind farms studied in the reviewed literature and the Project showed that the key findings are likely to be relevant to the proposed Coopers Gap Wind Farm.

Noise

In the reviewed literature, the health impacts associated with audible noise from wind farms has attracted the most peer reviewed epidemiological studies in the field, noting that this is still a limited number (six studies published in 11 articles). The overall quality of these epidemiological studies on wind farms and health is rated as low due to methodological issues such as the selection bias of respondents and self-reporting of health impacts.

The key finding from the reviewed literature is that there is no scientific evidence that exposure to wind farm noise can cause adverse health impacts. While there is evidence that some people living in proximity to a wind farm may experience annoyance, there is no consistent evidence that wind farm noise directly causes annoyance, and it may be that these people’s annoyance stems from a number of factors including negative attitudes to the project.

Infrasound

In the reviewed literature, the health impacts associated with infrasound from wind farms has not attracted any peer reviewed epidemiological studies. A number of peer reviewed acoustic studies have been undertaken however.

The key finding from the reviewed literature is that there is no scientific evidence that exposure to wind farm infrasound can cause adverse health impacts. Levels of exposure to wind farm infrasound have consistently been found to be below the 85dBG threshold of human perception. There is no evidence of physiological effects from infrasound that is below the level of audibility. The infrasound emitted by wind farms has been found to be comparable to a number of other sources including coastlines, urban areas and other industrial processes.

Low Frequency Sound (or noise)

In the reviewed literature, the health impacts associated with low frequency sound from wind farms has not attracted any peer reviewed epidemiological studies. A number of peer reviewed acoustic studies have been undertaken however.

The key finding of the reviewed literature is that there is no scientific evidence that exposure to wind farm low frequency noise causes adverse health impacts. The amplitude modulating characteristics of wind farm noise (also referred to as 'swooshing') that have anecdotally been associated with annoyance are in the mid-high frequency range and would be measured through standard dBA noise assessments.

Shadow Flicker

In the reviewed literature, the health impacts associated with shadow flicker from wind farms has not attracted any peer reviewed epidemiological studies.

The key finding of the reviewed literature is that there is no scientific evidence that wind farm shadow flicker can cause adverse health impacts. There is negligible risk of seizure from modern three bladed wind turbines which rotate at a speed that is below the level to elicit a seizure response in photosensitive individuals.

International guidelines for layout and design of wind turbines are in place to reduce the potential for shadow flicker to cause annoyance.

Electromagnetic Radiation

In the reviewed literature, the health impacts associated with EMR from wind farms has not attracted any peer reviewed epidemiological studies.

The key finding of the reviewed literature is that there is no scientific evidence that wind farm EMR can cause adverse health impacts. There is anecdotal evidence that wind farms generate EMR at the same level as household appliances but no peer reviewed studies to confirm this is the case.

Appendix A: References

No	Source Name	Summary of Content	Topic	Include or Exclude
1	Australian Wind Energy Association (AusWEA), 2004. *The Noise Emissions Associated with Wind Farming in in Australia*, Sustainable Energy Australia.	Background paper on wind farm noise emissions prepared under a Renewable Energy Industry Development Programme grant.	Noise	Exclude, not peer reviewed not govt
2	Australian Wind Energy Association (AusWEA), nd.b. *Wind Farming, Electromagnetic Radiation and Interference*, Fact Sheet no. 10. Sustainable Energy Australia.	Short industry fact sheet on the subject of EMR form wind farms	EMR	Exclude, not peer reviewed not govt
3	Australian Wind Energy Association (AusWEA), nd.b. *Wind Farming and Noise*. Fact Sheet no. 6. Sustainable Energy Australia	Short industry fact sheet on the subject of noise from wind farms	Noise	Exclude, not peer reviewed not govt
4	Ahlbom IC, Cardis E, Green A, Linet M, Savitz D, Swerdlow A. Review of the epidemiologic literature on EMF and Health. *Environ Health Perspect*. 2001;109 Suppl 6:911–33.	Non-wind farm study examining the scientific evidence on electric and magnetic fields on human health	EMR	Include
5	Alford BR, Jerger JF, Coats AC, Billingham J, French BO, McBrayer RO. Human tolerance to low frequency sound. *J Occup Environ Med*. 1966;8(11):620.	Non-wind farm study examining the impacts of exposure levels from low frequency sound	Noise	Include
6	EPA. Definitions of terms. NSW industrial noise policy. Sydney: Environmental Protection Authority; 2000. p. 59.	NSW State Government policy framework for measuring and mitigating industrial noise	Noise	Exclude, too general
7	Bakker RH, Pedersen E, van den Berg GP, Stewart RE, Lok W, Bouma J. Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress. *Sci Total Environ*. 2012;425:42–51.	Epidemiological study on the association between distance between wind farms and reported health effects	Noise	Include
8	Barry H, Yeo S. *Review of the Australian wind industry 2011*. Canberra: The Clean Energy Council; 2011.	Industry commissioned study examining local and global economic and policy trends	N/A	Exclude, not peer reviewed not govt
9	Basner M, Babisch W, Davis A, Brink M, Clark C, Janssen S, et al. Auditory and non-auditory effects of noise on health. *Lancet*. 2013. Epub 2013/11/05.	Non-wind farm study reviewing the literature to present auditory and non-auditory impacts of noise on health	Noise	Include

10	Berglund B, Hassmen P, Job RFS. Sources and effects of low-frequency noise. *J Acoust Soc Am*. 1996;99(5):2985–3002.	Non-wind study using literature review to examine the sources and effects of low frequency noise	Noise	Include
11	Berglund B and Lindvall T, 1995. Community Noise. *Archives of the Center for Sensory Research*, 2(1).	Seminal WHO commissioned study providing exposure and effects of various noise sources and guidelines	Noise	Include
12	Bolin, K, Bluhm, G, Eriksson, G & Nilsson, ME, 2011, "Infrasound and low frequency noise from wind turbines: exposure and health effects," *Environmental Research Letters* 6: 035103.	Literature review of primarily acoustic studies examining infrasound and low frequency sound from wind turbines	Noise	Include
13	Bullmore A, Peplow A. Sound propagation from wind turbines. In: Bowdler R, Leventhall G, editors. *Wind turbine noise*. United Kingdom: Multi-Science Publishing Co. Ltd.; 2012.	Book reviews current knowledge on noise and provides an objective and accurate assessment of wind turbine noise	Noise	Exclude, not peer reviewed not govt
14	Butler JS, Burkhauser RV, Mitchell JM, Pincus TP. Measurement error in self-reported health variables. *Rev Econ Stat*. 1987;69(4):644–50.	Non-wind farm study examining methodological limitations of self-reporting health issues	N/A	Exclude, too general
15	Canadian Wind Energy Association (CanWEA), 2009. *Addressing Concerns with Wind Turbines and Human Health*. CanWEA, Ottawa.	Industry publication refuting claims by Pierpont on health effects of wind farms by citing various evidence	N/A	Exclude, not peer reviewed not govt
16	Castleden, WM, Shearman, D, Crisp, G & Finch, P, 2011, "The mining and burning of coal: effects on health and the environment," *Medical Journal of Australia* 195(6): 333-335.	Study discussing the effects of mining and burning coal on health and the environment	N/A	Exclude, not specific to wind farms
17	Chapman, Simon, 2010, *Croakey*, 23 Feb 2010	Blog by Professor of Public Health Sydney University on the issue of wind farm and health	Noise Shadow flicker EMR	Exclude, not specific to wind farms
18	Chapman S, 2010. Personal Communication. Using the methodology of Covello VT, Von Winterfeldt D, Slovic P (1986) Communicating scientific information about health and environmental risks: problems and opportunities from a social and behavioural perspective. In:	Personal communication with Simon Chapman, Professor of Public Health Sydney University	N/A	Exclude, not peer reviewed not govt

	Covello, V., Lave, L., Maghissi, A., Uppuluri, V.R.R. (eds.) *Uncertainties in risk assessment and management*. New York: Plenum.			
19	Chatham-Kent Public Health Unit, 2008: *The Health Impact of Wind Turbines: A Review of the Current White, Grey, and Published Literature*. Chatham-Kent Municipal Council, Chatham Ottawa.	Review of the literature on wind farms and health undertaken by Public Health agency in Canada	Noise Shadow Flicker	Include
20	Colby DW, Doby R, Leventhall G, Lipscomb DM, McCunney RJ, Seilo MT, Søndergaard B, 2009. *Wind Turbine Sound and Health Effects - An Expert Panel Review*. Prepared for the American Wind Energy Association and the Canadian Wind Energy Association.	Scientific advisory panel established by the American and Canadian Wind Energy Industry to review the literature on scientific evidence of wind farms and health	Noise	Exclude, not peer reviewed not govt
21	Danielsson AKE, Landstrome ULF. Blood pressure changes in man during infrasonic exposure. *Acta Medica Scand*. 2009;217(5):531–35.	Non-wind farm study on impacts of exposure to infrasound	Noise	Include
21	Department of Trade and Industry UK (DTI), 2006. The measurement of low frequency noise at three UK wind farms: URN No: 06/1412 issued by the DTI in July 2006.	Acoustic study examining the measurement of low frequency noise at three locations in the UK	Noise	Include
22	Ellenbogen JM, Grace S, Heiger-Bernays WJ, Manwell JF, Mills DA, Sullivan KA, et al. *Wind turbine health impact study: Report of independent expert panel*. Massachusetts: Massachusetts Department of Public Health; 2012.	Expert panel commissioned by Massachusetts Government to conduct review of scientific literature on health impacts of wind farms	Noise Shadow Flicker	Include
23	Environment Protection and Heritage Council (EPHC), 2009. *National Wind Farm Development Guidelines - Public Consultation Draft*. Commonwealth of Australia, Adelaide.	Draft national guidelines (never finalised) published by the EPHC which is comprised of Federal and State Governments in Australia. Seen to represent best practice.	Noise Shadow Flicker, EMR	Include
24	Epstein, PR, Buonocore, JJ, Eckerle, K, Hendryx, M, Stout, BMI, Heinberg, R, Glustrom, L, 2011, "Full cost accounting for the life cycle of coal," *Annals of New York Academy of Sciences* 1219: 73-98.	Study examining the full cost accounting of the life cycle of coal	N/A	Exclude, not specific to wind farms
25	Evans T, Cooper J, Lenchine V. *Infrasound levels near windfarms and in other environments*. Environmental Protection Authority South Australia; 2013 [Viewed April 2013].	Acoustic study commissioned by the South Australian EPA to measure infrasound	Noise	Exclude, not specific to wind farms

26	Harding G, Harding P, Wilkins A. Wind turbines, flicker, and photosensitive epilepsy: Characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them. *Epilepsia*. 2008;49(6):1095–98.	Scientific study examining the conditions where shadow flicker may elicit a seizure and what this means for modern wind turbines.	Shadow Flicker	Include
27	Health Protection Agency, 2010, *Health Effects of Exposure to Ultrasound and Infrasound: Report of the independent Advisory Group on Non-ionising Radiation, Health Protection Agency Centre for Radiation, Chemical and Environmental Hazards*, Chilton, Didcot, Oxfordshire, UK	Public agency study examining the health effects of exposure to ultrasound and infrasound	Infrasound	Include
28	HGC Engineering, 2007. *Wind turbines and sound: Review and best practice guidelines*. CanWEA, Ottawa.	Study commissioned by Canadian wind energy industry to develop best practice guidelines for wind turbines and sound	Noise	Exclude, not peer reviewed not govt
29	Hillier S, Grimmer-Somers K, Merlin T, Middleton P, Salisbury J, Tooher R, et al. FORM: an Australian method for formulating and grading recommendations in evidence-based clinical guidelines. *BMC Med Res Methodol*. 2011;11:23. Epub 2011/03/02.	Non-wind farm study for assessing and appraising evidence in clinical studies	N/A	Exclude, not specific to wind farms
30	International Epidemiological Association. *Dictionary of epidemiology*. Porta M, editor. Oxford: Oxford University Press; 2008.	Dictionary of epidemiology used to inform NHMRC, 2014 Glossary	N/A	Exclude, not specific to wind farms
31	Jakobsen J. Infrasound emission from wind turbines. *J Low Freq Noise V A*. 2005;24(3):145–55.	Review of acoustic studies carried out for various wind turbine models and wind farms sites to measure infrasound	Noise	Include
32	Johnston DW, Propper C, Shields MA. Comparing subjective and objective measures of health: Evidence from hypertension for the income/health gradient. *J Health Econ*. 2009;28(3):540-52. Epub 2009/05/02.	Non-wind farm study examining methodological issues around self-reporting of health outcomes	N/A	Exclude, not specific to wind farms
33	Kalveram KT, 2000. How Acoustical Noise Can Cause Physiological and Psychological Reactions. *Proceedings of the 5th International Symposium of Transport Noise and Vibration*. St. Petersburg, Russia: East European Acoustical Society.	Conference proceedings on how noise can cause non-auditory reactions in exposed populations	Noise	Exclude, not peer reviewed not govt
34	Knopper, LD & Ollson, CA, 2011, "Health effects and wind turbines: A review of the literature," *Environmental Health* 10(1): 78.	Literature review conducted by consultants on	Noise	Include

		wind farms and health	Shadow Flicker	
35	Krogh CME, Gillis L, Kouwen N, Aramini J. WindVOiCe, a self-reporting survey: Adverse health effects, industrial wind turbines, and the need for vigilance monitoring. *Bull Sci Tech Soc*. 2011;31(4):334–45.	Epidemiological study on the association between distance between wind farms and reported health effects	Noise	Include
36	Laszlo HE, McRobie ES, Stansfeld SA, Hansell AL. Annoyance and other reaction measures to changes in noise exposure — a review. *Sci Total Environ*. 2012;435-436:551-62. Epub 2012/08/21.	Non-wind farm study examining annoyance and nuisance reactions to noise exposure	Noise	Include
37	Leventhal G, 2006. Infrasound from Wind Turbines – Fact, Fiction or Deception. *Canadian Acoustics*, 24(2): 29-36.	Review of the literature to determine the weight of evidence for infrasound related health impacts from wind farms	Noise	Include
38	Leventhall, Geoff, 2010) Submission and Appendices to the Senate Inquiry: The Social and Economic Impact of Rural Wind Farms, available at http://www.aph.gov.au/senate/committee/clac_ctte/impact_rural_wind_farms/submissions.htm (accessed 2 June 2011)	Submission to Senate committee enquiry on social and economic impact of rural wind farms	Noise	Exclude, not peer reviewed not govt
39	Lockwood AH, Walker-Hood K, Rauch M, Gottlieb B. *Coal's Assault on Human Health. A report from Physicians for Social Responsibility*; 2009.	Book on the impacts of coal on human health	N/A	Exclude, not peer reviewed not govt
40	Macintosh A, Downie C, 2006. *Wind Farms: the facts and the fallacies*. The Australia Institute: Discussion Paper No. 91.	Discussion paper issued by the Australian Institute (Canberra based think tank) on a range of issues relevant to wind farms	N/A	Exclude, not peer reviewed not govt
41	Markandya A & Wilkinson P, 2007. Electricity generation and health. *The Lancet*, 370: 979-990.	Non wind farm related study on the association between electricity generation and health	N/A	Exclude, too general
42	Merlin T, Newton S, Ellery B, Milverton J, Farah C. *Systematic review of the human health effects of wind farms*. Canberra: National Health and Medical Research Council; 2013.	Detailed literature review commissioned by the NHMRC to inform their draft information paper (2014) on the subject of wind farms and health	Noise, Shadow Flicker, EMR	Include
43	Mills JH, Osguthorpe JD, Burdick C, Patterson J, Mozo B. Temporary threshold shifts produced by exposure to low-frequency noises. *J*	Non-wind farm study examining the scientific evidence and clinical based trials on health	Noise	Include

	Acoust Soc Am. 1983;73:918.	effects from low frequency noise		
44	Ministry of the Environment, 2007. Acoustic consulting report prepared for the Ontario Ministry of the Environment. *Wind turbine facilities noise issues*. Aiolos report number 4071/2180/AR155Rev3, Queens Printer for Ontario, Ontario.	Acoustic study commissioned by the Ontario State Government examining different noise issues associated with wind turbines and jurisdictional approaches	Noise	Include
45	Minnesota Department of Health, 2009. *Public Health Impacts of Wind Turbines*.	Report by the Minnesota Department of Health examining range of issues associated with wind farms and health	Noise, Shadow Flicker	Include
46	Morris M. Waterloo wind farm survey. 2012 [Viewed 18 January 2013]; Available from: www.wind-watch.org/news/wp-content/uploads/2012/07/Waterloo-Wind-Farm-Survey-April-2012-Select-Committee.pdf.	Non-peer reviewed epidemiological study undertaken in Australia to examine self-reported health effects from shadow flicker	Shadow Flicker	Exclude, not peer reviewed not govt
47	National Research Council, 2007. *Environmental Impacts of Wind-Energy Projects. Committee on Environmental Impacts of Wind Energy Projects*, Board on Environmental Studies and Toxicology, Division on Earth and Life Studies.	Report conducted by the US National Research Council to examine general environmental impacts associated with wind farms	N/A	Include
48	NHMRC. *NHMRC public statement: wind turbines and health. Canberra*: National Health and Medical Research Council; 2010.	NMHRC public statement on wind farms and health based on the rapid review of evidence	Noise, Shadow Flicker, EMR	Include
49	NHMRC. *Wind turbines and health: A rapid review of the evidence. Canberra:* National Health and Medical Research Council; 2010a.	NMHRC review of the available scientific evidence on wind farms and health	Noise, Shadow Flicker, EMR	Include
50	NHMRC. NHMRC levels of evidence and grades for recommendations for developers of guidelines. Canberra: National Health and Medical Research Council; 2009.	NHMRC publications on how levels of scientific evidence can be applied in practice	N/A	Exclude, not specific to wind farms
51	NHMRC. NHMRC additional levels of evidence and grades for recommendations for developers of guidelines. Stage 2 consultation. Early 2008 - end June 2009. Canberra: National Health and Medical	NHMRC publications on how levels of scientific evidence can be applied in practice	N/A	Exclude, not specific to wind farms

	Research Council; 2008.			
52	Nissenbaum M, Aramini J, Hanning C. Effects of industrial wind turbine noise on sleep and health. *Noise Health*. 2012;14(60):237–43.	Epidemiological study on the association between distance between wind farms and reported health effects	Noise	Include
53	Pedersen E, Persson Waye K. Wind turbine noise, annoyance and self-reported health and well-being in different living environments. Occup Environ Med. 2007;64(7):480–86. Epub 2007/03/03.	Epidemiological study on the association between distance between wind farms and reported health effects	Noise	Include
54	Pedersen E, Waye KP. Perception and annoyance due to wind turbine noise — A dose-response relationship. J Acoust Soc Am. 2004;116(6):3460–70.	Epidemiological study on the association between distance between wind farms and reported health effects	Noise	Include
55	Persson Waye K. Effects of low frequency noise on sleep. Noise Health. 2004;6(23):87–91.	Epidemiological study on the association between distance between wind farms and reported health effects	Noise	Include background evidence used by NHMRC
56	Pedersen E. Health aspects associated with wind turbine noise — Results from three field studies. Noise Cont Eng J. 2011;59(1):47–53.	Epidemiological study on the association between distance between wind farms and reported health effects	Noise	Include
57	Pedersen, E & Larsman, P 2008, 'The impact of visual factors on noise annoyance among people living in the vicinity of wind turbines', *Journal of Environmental Psychology*, vol. 28, no. 4, pp. 379–389.	Epidemiological study on the association between distance between wind farms and reported health effects	Noise	Include
58	Pedersen, E, van den Berg, F, Bakker, R & Bouma, J 2009, 'Response to noise from modern wind farms in The Netherlands', *Journal of the Acoustical Society of America*, vol. 126, p. 634.	Epidemiological study on the association between distance between wind farms and reported health effects	Noise	Include
59	Rogers A, Manwell J & Wright S, 2006. *Wind Turbine Acoustic Noise.* Renewable Energy Research Laboratory, University of Massachusetts at Amherst.	University study examining the various noise characteristics and associated acoustic measurements appropriate for wind farms	Noise	Exclude, not peer reviewed not govt
60	PHAA 2010, Safe climate Policy at http://www.phaa.net.au/policyStatementsInterim.php#e	Association publication or policy statement on safe climate policy	N/A	Exclude, not peer reviewed not govt
61	PHAA 2011, Nuclear Industry Policy at	Association publication or policy statement on		Exclude, not peer

	http://www.phaa.net.au/policyStatementsInterim.php#e	nuclear industry policy		reviewed not govt
62	Rideout K, Copes R, Bos C. *Wind turbines and health*. Vancouver: National Collaborating Centre for Environmental Health; 2010.	Review of the scientific evidence on wind farms and health conducted by the Canadian National Collaborating Centre for Environmental Health	Noise, Shadow Flicker	Include
63	Roberts M, Roberts J. *Evaluation of the scientific literature on the health effects associated with wind turbines and low frequency sound*. Illinois, USA: Wisconsin Public Service Commission; 2009 [Viewed 15 November 2012]; Available from: http://www.maine.gov/dhhs/mecdc/environmental-health/documents/wind-turbine-wisconsin-assessment.pdf.	Report by consultants Exposure commissioned by the Wisconsin Government on the review of the scientific evidence of wind farms and health effects	Noise, Shadow Flicker	Include
64	Shepherd D, McBride D, Welch D, Dirks KN, Hill EM. Evaluating the impact of wind turbine noise on health-related quality of life. *Noise Health*. 2011;13(54):333–39.	Epidemiological study on the association between distance between wind farms and reported health effects	Noise	Include
65	Smedley A, Webb A, Wilkins, A, 2010. 'Potential of wind turbines to elicit seizures under various meteorological conditions' *Epilepsia*, Volume 51, issue 7 (July 2010), p. 1146-1151.	Scientific study examining the conditions where shadow flicker may elicit a seizure and what this means for modern wind turbines.	Shadow flicker	Include
66	Sustainable Development Commission (United Kingdom), 2005. *Wind Power in the UK: A guide to the key issues surrounding onshore wind power development in the UK*, Government of the United Kingdom, England. Available at: http://www.sdcommission.org.uk/	UK government guide to best practice wind farm development focussing on community involvement in the development process	N/A	Include
67	Sustainable Energy Authority Victoria, 2003. *Policy and planning guidelines for development of wind energy facilities in Victoria*. Sustainable Energy Authority Victoria, Melbourne.	Policy and planning guidelines developed by the Victorian State Government (recently amended to 2012 version)	N/A	Include
68	Turnbull C, Turner J and Walsh D. April 2012. 'Measurement and level of infrasound from wind farms and other sources' in *Acoustics Australia* vol 40, no. 1.	Australian acoustic study examining the infrasound emitted by various sources including natural and industrial and comparing to wind farms	Noise	Include
69	Van den Berg G, Pedersen E, Bouma J, Bakker R. Project WINDFARMperception: Visual and acoustic impact of wind turbine farms on residents. Final report. University of Groningen; Goeteborg	Epidemiological study on the association between distance between wind farms and	Noise	Include

	University; University Medical Centre, Groningen; 2008 [updated 2012/11/13/06:24:13; Viewed 13 November 2012]; Available from: http://www.epaw.org/documents/WFp-final-1.pdf.	reported health effects		
70	Van den Berg GP, editor. Do wind turbines produce significant low frequency sound levels. *11th International Meeting on Low Frequency Noise and Vibration and its Control; 2004*; Maastricht, The Netherlands.	Conference proceedings on whether wind turbines produce significant levels of low frequency sound	Noise	Exclude, not peer reviewed not govt
71	Verkuijlen E, Westra C, editors, 2008. *Shadow hindrance by wind turbines*. European Wind Energy Conference; 1984; Hamburg, Germany; cited in Harding et al.	Conference proceedings published in book format on shadow flicker from wind turbines	Shadow flicker	Exclude, not peer reviewed not govt
72	Victorian Department of Health, 2013. *Wind farms, sound and health: Technical Information*, State Government of Victoria	Publication by the Victorian Department of Health on wind farms, sound and health	Noise	Include
73	Windrush Energy, 2004. *The health effects of magnetic fields generated by wind turbines*. Palgrave, ON: Windrush Energy.	Consultant report into the EMR from wind farms which showed that it was within the levels of household appliances	EMR	Exclude, not peer reviewed not govt
74	Wertheimer N, Leeper E. Electrical wiring configurations and childhood cancer. *Am J Epidemiol*. 1979;109(3):273–84. Epub 1979/03/01.	Non-wind farm study into the association between electrical wiring and health effects such as childhood cancer	EMR	Include
75	World Health Organization (WHO), 2004. *Energy, sustainable development and health*. Background document for the Fourth Ministerial Conference on Environment and Health, 23-25 June 2004, Geneva.	WHO background document to a ministerial meeting in 2004 covering energy production and health issues	N/A	Exclude, not specific to wind farms
76	WHO, 2011. *Burden of disease from environmental noise*. World Health Organization; 2011 [Viewed April 2013]; Available from: http://www.euro.who.int/en/what-we-publish/abstracts/burden-of-disease-from-environmental-noise.-quantification-of-healthy-life-years-lost-in-europe.	WHO study that examines the impacts of community noise on health, vulnerable populations and appropriate guidelines for measuring health effects	N/A	Include
77	WHO, 2012. What are electromagnetic fields? Typical exposure levels at home and in the environment. World Health Organization; 2012 [Viewed 20 November 2012]; Available from:	WHO study that examines typical exposures to electromagnetic fields in the house and	EMR	Include

	http://www.who.int/peh-emf/about/WhatisEMF/en/index3.html.	environment		
78	WHO, 2002. Establishing a dialogue on risks from electromagnetic fields. Geneva: World Health Organization; 2002 [Viewed April 2013]; Available from: http://www.who.int/peh-emf/publications/en/EMF_Risk_ALL.pdf. 25	WHO study that examines exposures to electromagnetic fields and general risk issues	EMR	Include
79	WHOQOL. The World Health Organization quality of life assessment (WHOQOL): position paper from the World Health Organization. Soc Sci Med. 1995;41(10):1403–9. Epub 1995/11/01.	The WHO quality of life assessment indicators	N/A	Exclude, not specific to wind farms