Exploring the Association between Proximity to Industrial Wind Turbines and Self-Reported Health Outcomes in Ontario, Canada

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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ABSTRACT

Background: Wind turbines are a form of renewable energy, which generate electricity from wind energy, a practice dating back over 100 years. More recently, large-scale wind energy developments have started to employ one or several industrial wind turbines, which produce the majority of wind energy in Ontario. The production of electricity from the movement of industrial wind turbine motor blades creates both mechanical and aerodynamic noise. This type of environmental noise is a growing public health concern, especially for residents living close to industrial wind turbines. A body of evidence now exists to suggest that industrial wind turbine noise can impair health and contribute to annoyance and sleep disturbance. However, in Ontario, little is known about how industrial wind turbines impact people living in their vicinity.

Objectives: This investigation was a cross-sectional study involving eight Ontario communities that contain greater than ten industrial wind turbines. The objectives of this study were to explore the association between proximity to industrial wind turbines and self-reported health effects, specifically quality of life (both physical and mental health) and sleep disturbance, in residents living close to wind turbines. Dose-response relationships were also explored in an attempt to investigate acceptable exposure levels and appropriate setback distances for industrial wind turbines.

Methods: Eight wind farms in Ontario were selected for analysis. For this cross-sectional study, the 'Quality of Life and Renewable Energy Technologies Study' survey was used to measure the impact of industrial wind turbines on health. Using Canada Post's Unaddressed Admail Service, surveys were sent to 4,876 residences near industrial wind turbines in these eight communities. Survey responses were sent back to the University of Waterloo and data from the surveys were used for analysis. Descriptive analyses were performed and multiple regression models were run to investigate the effect of the main independent variable of interest (distance to nearest industrial wind turbine) on the various outcome variables. Descriptive statistics, including means and standard deviations were performed on a number of dependent and independent variables including age, sex, time in home, number of industrial wind turbines within 2,000 meters and sleep and health outcomes.

Results: In total, 412 surveys were returned (8.45% response rate); 16 of these survey respondents did not provide their home address. Therefore, 396 surveys were included in the analysis. The mean self-reported distances of survey respondents to wind farms was 2,782 meters ±3,950 meters (range: 0.40-55,000 meters). The mean calculated distance from residence to the closest industrial wind turbine was 4,523 meters ±4,420 meters (range: 316-22,661 meters). The difference between the calculated and perceived distance measurements was statistically significant (P<0.001) with survey respondents reporting that they live, on average, 1,741 meters closer to wind farms than they actually do. The relationship between Pittsburgh Sleep Quality Index and ln(distance) was found to be statistically significant (P=0.01) when controlling for age, gender and county, meaning that as distance increased (move further away from an industrial wind turbine), Pittsburgh Sleep Quality Index decreased (i.e. sleep improved) in a logarithmic relationship. Among the eight Wind Turbine Syndrome index variables, the relationship between vertigo and ln(distance) was statistically significant (P<0.001) when controlling for age, gender, and county. Additionally, the relationship between tinnitus and ln(distance) approached statistical significance (P=0.08) when controlling for age, gender and county. Both vertigo and tinnitus were worse among participants living closer to industrial wind turbines.

Conclusion: Study findings suggest that industrial wind turbines could have an impact on health. Using a sample of rural Ontario residents (although not necessarily representative of the target population), this study explored the quality of life (both physical and mental health) and sleep disturbance of residents living in the vicinity of industrial wind turbines. However, because of study limitations, there are many questions still to be answered before firm conclusions can be drawn. Based on the findings of this study it is recommended that further studies be carried out to examine the effects of low-level stressors, such as industrial wind turbine noise, on health. Specifically, study findings suggest that future research should focus on the effects of industrial wind turbine noise on sleep disturbance and symptoms of inner ear problems. Although the study findings could suggest that there is a possible association between various health outcomes and how far someone lives from an industrial wind turbine, it is important to remember that there are limitations to these conclusions.

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First, I would like to thank my committee members, Dr. Phil Bigelow, Dr. Jane Law, Dr. Shannon Majowicz and Dr. Jeff Aramini for their support over the past two years. Their expertise and constructive criticism were instrumental in the development of this thesis project. I would also like to give a big thank you to Tanya Christidis for all her help, encouragement, late night chats, texts, phone calls, e-mails and, most importantly, for her friendship. Each and every one of you had a large influence on my work and I could not have done it without you. Furthermore, I would like to thank Erin Harvey, from the Faculty of Mathematics for her statistical expertise and consulting. I would also like to express my appreciation for my family and friends who have supported me throughout this process, especially my Mom and Dad who always said "YOU CAN DO IT" and Waldo for his ongoing love, motivation and encouragement. Finally, thank you to the Ontario Research Chair in Renewable Energy Technologies and Health for providing funding for this project.

For my Mom and Dad

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 – INTRODUCTION

1.1 General Problem Area

Renewable energy sources, such as wind, solar and bioenergy, have been used for centuries; however, they are starting to play an increasingly significant role in today's energy scenario. Wind turbines are a form of renewable energy, which generate electricity from the mechanical movement of blades by the wind - a practice dating back over 100 years (Shepherd et al., 2011). Ontario's production of renewable energy, specifically wind, is rapidly expanding and currently Ontario is the national leader in installed wind energy capacity (Ferguson-Martin & Hill, 2011). Most of Ontario's installed wind energy is in the form of large-scale wind energy developments, which employ one or several industrial wind turbines. Industrial wind turbines range in size, but are usually over 90 meters in height and can each generate anywhere from 0.65 to 2.5 MW of power (CANWEA, 2011).

Typically, a group of several industrial wind turbines located in close proximity to one another are referred to as a wind farm. Wind farms are a new source of environmental noise (Pedersen, 2011) because the inflowing airstream is rarely stable as wind velocity and direction are always changing. Wind velocity increases with height, especially at night and is affected by nearby structures (e.g. other industrial wind turbines), which may result in inflow turbulence. All of these factors result in what has been described as a "swishing" and "thumping" noise (i.e. aerodynamic noise). This aerodynamic noise is poorly masked by ambient noise and is reported to be more annoying than other sources of environmental noise (Hanning, 2012).

1.2 Relevance and Significance

The impact of industrial wind turbine environmental noise on health and well-being has not been well established and is still under debate (Pedersen, 2011). A few studies have shown that when industrial wind turbines are placed in residential areas they may cause noise annoyance (Persson Waye and Öhrström, 2002; Pedersen and Persson Waye, 2004; Pedersen and Persson Waye, 2007; Pedersen et al., 2008; Pedersen et al., 2010). However, only a small number of peer-reviewed studies currently exist which have examined the health impact of industrial wind turbine noise (Shepherd et al., 2011). Being able to quantify the impact of industrial wind turbine noise on health will help to inform industrial wind turbine operational guidelines (e.g. appropriate set-back distances) (Shepherd et al., 2011), as well as policy and implementation of wind turbines, and is therefore very important as wind farms are developing and growing rapidly.

With the increased desire to generate sustainable energy and to reduce the use of fossil fuels, industrial-scale harvesting of wind energy has increased in the last decade (Shepherd et al., 2011). Although the number of operational industrial wind turbines is rapidly growing globally (Pedersen et al., 2010), not much is known about the impact that industrial wind turbines may have on residents living nearby (Pedersen and Persson Waye, 2004). Currently in Ontario minimal research has been done to investigate the health impacts of industrial wind turbines on people living in their vicinity (Pedersen & Persson Waye, 2004). More specifically, one of the key gaps in evidence is the health effects from long-term exposure to low frequency noise from industrial wind turbines (Rideout et al., 2010).

It is clear that the increasing number and size of wind farms in Ontario calls for further investigation into the impact of industrial wind turbines on residents living nearby industrial wind turbines in order to minimize any adverse health effects that may occur (Pedersen et al., 2009). In particular, it is important to look at dose-response relationships to try to understand acceptable exposure levels (Pedersen & Waye, 2008), so that possible adverse health effects can be avoided (Pedersen et al., 2009). Furthermore, policy makers are asking questions and demanding information about the possible link between industrial wind turbines and health so that they are able to better inform setback distances (Shepherd et al., 2011). In May 2012, Ontario's Chief Medical Officer of Health concluded that there is a shortage of Canadian epidemiological evidence proving any cause and effect relationship between industrial wind turbines and adverse health effects (CMOH, 2010). Therefore, this study will help add to the body of knowledge surrounding exposure to industrial wind turbines and health. It is hypothesized that individuals living closer to industrial wind turbines may experience a lower quality of life (both physical and mental health) and have greater sleep disturbance than those living further away from industrial wind turbines. Specifically, it is hypothesized that industrial wind turbines may be negatively related to quality of life (both physical and mental health) and positively related to sleep disturbance (see Figure 1 below).

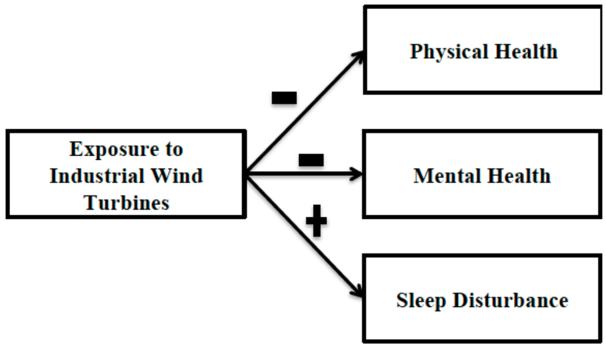

Figure 1*: Conceptual Model Showing Hypothesized Relationships between Exposure to Industrial Wind Turbines and Outcome Variables (relationships between outcome variables not shown)*

1.3 Research Objectives

The objectives of this research were to study eight Ontario wind farm communities in order to;

1) explore the self-reported adverse health effects related to mental health, physical health and sleep disturbance from exposure to industrial wind turbines and;
2) explore possible dose-response relationships.

As the number and size of wind farms in Ontario continue to increase, it is critical that the impact of industrial wind turbines on human health be examined in order to avoid and minimize any adverse health effects that may occur.

CHAPTER 2 – LITERATURE REVIEW

This literature review will first describe the current context for wind energy and industrial wind turbine development in Ontario. Then, the overall potential health effects of industrial wind turbines will be examined. Following this, impacts of noise from industrial wind turbines will be discussed as this is where many current investigators are focusing their research. Finally, a summary of reported health effects related to industrial wind turbines noise will be provided as will a discussion about dose-response relationships and causality.

2.1 Wind Energy in Ontario

In 2003, the newly elected Liberal government implemented supportive wind power policies, which included renewable electricity targets of 5% by 2007 and 10% by 2010 (Ontario Liberal Party, 2003). In an attempt to meet these targets, the Ontario Government issued tenders for renewable energy power purchase agreements in 2004 and 2005 (Ferguson-Martin & Hill, 2011). Next, in 2006, the government created a Feed-in-Tariff program called the Renewable Energy Standard Offer Program (RESOP). This Feed-in-Tariff program guaranteed rates for energy generated from renewable sources (i.e. solar photovoltaic, biogas, biomass, landfill gas, on-shore and off-shore wind and water power) (MOE, 2010). Although this program offered 11 cents/kWh price for wind, there was no guarantee of being connected to the grid and only wind projects smaller than 10MW were included (Ferguson-Martin & Hill, 2011).

In the spring of 2009, the RESOP was expanded and the Green Energy and Economy Act (GEA) was passed by the Ontario Government (Ferguson-Martin & Hill, 2011). This act was created with the goals of expanding Ontario's production of renewable energy, encouraging energy conversation and increasing the number of clean-energy jobs (MOE, 2010). As part of the GEA, the tariff levels were raised. Currently, Ontario's Feed-in-Tariff program provides a tariff of 11.5 cents/kWh for new wind energy development (CanWEA, 2012). The GEA created a single access point for government approvals, removed the requirement of municipal approval and made it mandatory for utility companies to feed new renewable energy projects into the grid. This new regulation for renewable energy projects also included minimum setbacks for industrial wind turbines (i.e. 550 meters from residences and other noise receptors[1]) and mandatory community consultations (Ferguson-Martin & Hill, 2011).

In late 2010, the Ontario government announced their Long Term Energy Plan (LTEP). According to the LTEP, the Ontario government aims to have 10,700 MW of installed capacity of renewable energy (not including hydro) by 2018, with about 7,500 MW of that being supplied by wind energy (CanWEA, 2012).

Recently, the Ontario Government released the results of a review of the Feed-in-Tariff program and made a new commitment to acquire all of the wind energy required to meet the 2018 target by 2015. As of 2012, Ontario's installed wind capacity was approximately 2,043 MW with more than 3,600 MW of new wind energy already committed to, or contracted, to be built (CanWEA, 2012). As of 2012, Canada has an installed wind energy capacity of 6,568 MW distributed across 162 sites (CanWEA, 2012) with Ontario being the national leader in installed wind energy capacity, contributing to about one-third of national wind energy development between 1995 and 2012. Specifically, Ontario has been quite aggressive in deploying wind since 2005

[1] Receptors include buildings, dwellings, campsites, places of worship, and institutions (MOE, 2008)

(Ferguson-Martin & Hill, 2011). This is most likely due to Ontario's supportive wind power policies and also because Ontario's Great Lakes are a major source of wind resources with high onshore wind speeds near the lakes, especially in the Bruce Region (Ferguson-Martin & Hill, 2011). With the majority of industrial wind turbines in Ontario having been built after 2006, as of 2012 there are about 46 wind farm sites and a total of about 1,100 industrial wind turbines in Ontario (CanWEA, 2012).

2.2 Health Effects of Wind Turbines

Even though wind turbines have been used as a source of electricity globally, industrial wind turbines and vast decentralized wind farms are a recent phenomenon in Ontario. As with the introduction of any new technology, concerns about the health impacts have been raised. The relationship between reported health effects and industrial wind turbines is an ongoing debate. Minimum setback distances (i.e. 550 meters in Ontario) based on a 40-decibel noise limit (MOE, 2013) have been created "to reduce or avoid potential complaints from, or potential effects to, people living in proximity to wind turbines" (Knopper & Ollson, 2011). However, as the number of wind farms increase so does the number of reported health effects and community concerns. These concerns primarily relate to the following issues:

1. Industrial wind turbine design and infrastructure (e.g. visual impact, electromagnetic fields associated with generation and transmission of electricity, shadow flicker and ice throw from rotor blades, and structural or mechanical failure) and;

2. Industrial wind turbine noise and vibration (e.g. levels of audible noise [including low frequency noise] and infrasound).

It is possible that these issues, if left unmanaged, could result in negative health impacts (Knopper & Ollson, 2011). Although industrial wind turbines differ from traditional environmental stressors (e.g. heat, crowding, air pollution, odours, etc.) they may still cause stress through noise, vibration, visual disturbance and potentially some other unknown pathways. Therefore, industrial wind turbines may be environmental stressors to some people and their impacts on health should be examined.

According to Shepherd et al. (2011), “wind turbine farms can negatively impact health, specifically quality of life, including quality of sleep and annoyance leading to a chronic stress response resulting in diminished physical and environmental quality of life”. However, there is a large array of reported health effects from industrial wind turbines. Self-reported surveys, case studies and complaints from residents living near wind farms have reported health effects including, but not limited to: decreased quality of life, sleep disturbance, annoyance, stress, inner ear problems, cardiac concerns, headaches, anger, depression, irritability, and fatigue (Pedersen & Persson Waye, 2004; Pedersen & Persson Waye, 2007; Pedersen et al., 2010; Minnesota Department of Health Environmental Health Division, 2009; Pierpont, 2009; Shepherd et al., 2011; Nissenbaum et al., 2011). The following symptoms – sleep disturbance, headaches, difficulty concentrating, irritability and fatigue – have been referred to as “wind turbine syndrome” (WTS) and are hypothesized to result from the low frequency sounds that industrial wind turbines generate (Pierpont, 2009). At this point in time there is little academic research on WTS. In particular, since wind farms are a new source of environmental noise, the impact of industrial wind turbine noise on health and well-being has not yet been well-established (Pedersen, 2011).

2.3 Noise from Wind Turbines

Industrial wind turbines produce sound. Sound can be described in two ways - by its sound pressure level (loudness), which is measured in decibels (dB), and by its frequency (pitch), which is measured in Hertz (Hz) (Rogers et al., 2006; Leventhall et al., 2003). Noise can be simply defined as “unwanted sound” (MOE, 2004) and perception of noise differs among people and places.

Industrial wind turbines produce two main types of noise: mechanical noise and aerodynamic noise. Mechanical noise (mainly motor noise from within the turbine) can contain discrete tone components, which are known to be more annoying than noise without tone. There are ways to substantially reduce mechanical noise. Aerodynamic noise from industrial wind turbines mainly comes from the flow of air around the blades. Sound pressure levels increase with tip speed and size of industrial wind turbine. Manufacturers have been able to reduce the mechanical noise to a level below the aerodynamic noise and thus, aerodynamic noise is usually the dominant noise from industrial wind turbines (Pedersen & Persson Waye, 2004).

The inflowing airstream towards industrial wind turbines is rarely stable because wind velocity and direction are always changing. Wind velocity increases with height, especially at night and is affected by nearby structures (e.g. other industrial wind turbines), which may result in inflow turbulence. All of these factors result in what has been described as a “swishing” and “thumping” noise (i.e. aerodynamic noise), which is more annoying than other sources of environmental noise and is poorly masked by ambient (i.e. background) noise (Hanning, 2012). This aerodynamic noise is present at all frequencies, from infrasound (frequencies below 20Hz) to low frequency (frequencies below 200 Hz) to the normal audible range (Leventhall, 2006; Colby et al., 2009). The normal human ear can hear sounds at frequencies ranging from 20 Hz to 20,000 Hz (Rogers et al., 2006; Leventhall et al., 2003). In most cases, the sound from industrial wind turbines is described as infrasound. Although infrasound is usually inaudible, at high enough sound pressure levels, it can be audible to some people (Rogers et al., 2006; Leventhall et al., 2003).

Typical sound levels of a modern industrial wind turbine range from 98–104 dB(A) at a wind speed of 8 m/s, though this can vary depending on meteorological and ground conditions (Pedersen and Persson-Waye, 2007). For example, when 350-550 meters from an industrial wind turbine, the sound pressure level is normally in the range of 35 to 50 dB(A) (Rideout & Copes, 2010), which is comparable to indoor background sound (see Figure 2). Although this sound level is not usually sufficient enough to damage hearing, it may lead to sleep disturbance, annoyance and other health effects in residents living nearby industrial wind turbines (Rideout & Copes, 2010).

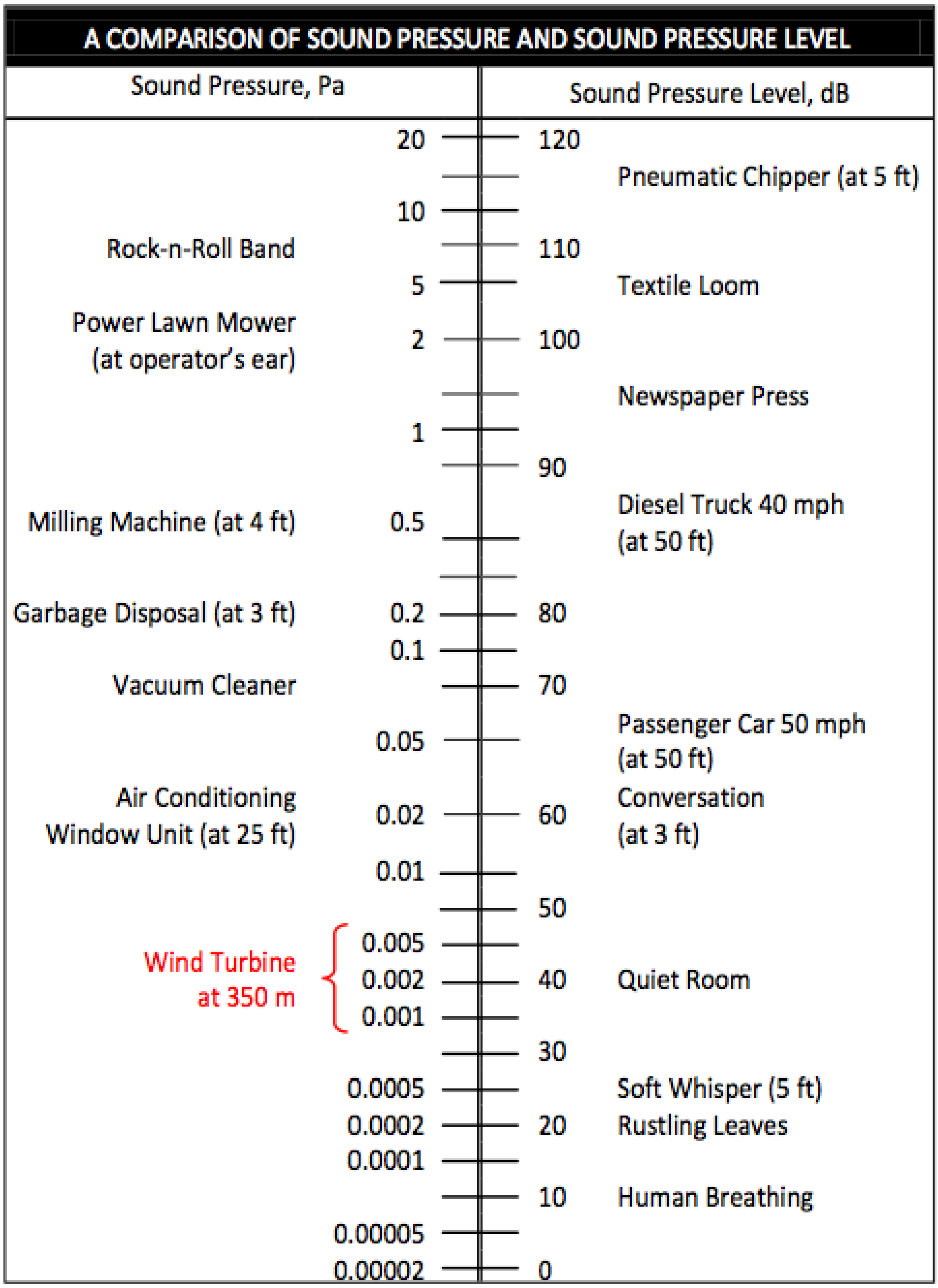

Figure 2: ***A Comparison of Sound Pressure and Sound Pressure Level (Wind Turbines in Relations to Other Sources) (Rideout & Copes, 2010)***

2.4 Reported Health Effects Related to Wind Turbine Noise

Possible adverse health effects as a result of industrial wind turbine noise have been a concern since the beginning of the modern wind power era in the 1970s, however the impact of industrial wind turbine noise on health and well-being is not yet well understood or established (Pedersen, 2011). In semirural or rural areas, wind farm noise is of particular interest because it is typically a "low amplitude noise impeding on a well-characterized and generally cherished soundscape" (Shepherd et al., 2011). There has been much discussion about whether or not wind farm noise poses a significant health threat to residents living nearby. Studies have shown that high sound pressure levels (loudness) of audible noise and infrasound have been associated with learning, sleep, and cognitive disruptions, stress, and anxiety (Leventhall et al., 2003; WHOE, 2009; Knopper & Ollson, 2011). More specifically, studies have suggested that industrial wind turbine noise (i.e. low-frequency sound energy below 20 Hz) can impact health, though this is still a topic under debate (Pierpont, 2009; Salt & Hullar, 2010; Bakker, 2012). In addition, industrial wind turbine noise may affect health by causing annoyance or disturbing sleep, which means that industrial wind turbine noise can be classified as community noise alongside industrial and transportation noise (Shepherd et al., 2011; Bakker, 2012).

Studies performed in Sweden and the Netherlands found direct relationships between modeled sound pressure levels from industrial wind turbines and self-reported perception of sound and annoyance (Pedersen et al., 2009; Pedersen and Waye, 2008; Pedersen and Waye, 2007; Pedersen and Waye, 2004; Bakker, 2012). Furthermore, case studies that involved qualitative analyses have shown a negative relationship between industrial wind turbine noise and well-being (Pedersen et al., 2007; Pierpont, 2009). A recent study by Shepherd et al. (2011), involving quantitative investigations of the impact of wind farms on Health Related Quality of Life (HRQOL), found that wind farm noise can negatively impact different aspects of HRQOL. Specifically they found that residents living within 2 km of an industrial wind turbine reported lower overall quality of life, physical quality of life, and environmental quality of life. Shepherd et al. (2011) also found that residents exposed to industrial wind turbine noise reported significantly lower sleep quality, and rated their environment as less restful. Another recent study compared sleep and general health outcomes of participants living close to industrial wind turbines and those living further away from industrial wind turbines (Nissenbaum et al., 2012). This study found that participants living within 1.4 km of an industrial wind turbine had worse sleep, were sleepier during the day, and had worse SF-36 mental component scores compared to those living further than 1.4 km away (Nissenbaum et al., 2012). Other studies have also observed correlations between industrial wind turbine noise, annoyance, and sleep disruption (Pedersen & Waye, 2008; van den Berg et al., 2008; Bakker, 2012).

2.5 Dose-Response Relationships

Rothman & Greenland (2005) define ‘cause’ (of a specific disease) as “an antecedent event, condition, or characteristic that was necessary for the occurrence of the disease at the moment it occurred, given that other conditions are fixed”. In other words, a cause of a disease is an event, condition, or characteristic that must precede the disease and without this causes(s), the disease either would not have occurred or would not have occurred until some later point in time. Unfortunately, for biological effects, most and sometimes all of the components of a cause are unknown (Rothman and Greenland, 2005) and difficult to determine.

Sir Austin Bradford-Hill established nine criteria for causation. The nine criteria are a group of minimal conditions (see Table 1 below) necessary to provide adequate evidence of a causal relationship between an incidence and a consequence (i.e. does factor A cause disorder B). *Biological gradient*, one of Hill's criteria for causation, questions if there is a dose-response relationship. In general, a dose-response relationship means the greater the exposure, the greater the incidence of the effect. However, in some cases, just having the factor present can trigger the effect. In other cases, an inverse proportion can be found meaning that greater exposure leads to lower incidence (Bradford-Hill, 1965). In this study, 'distance to closest industrial wind turbine' was used as the 'dose' variable and 'health outcome' was used as the 'response' variable.

Table 1: Hill's Nine Criteria for Causation (Bradford-Hill, 1965)

Criterion	**Description**
Strength (of the association)	A small/weak association does not mean that there is not a causal effect, though the larger/stronger the association, the more likely that the association is causal.
Consistency (of the observed association)	The likelihood of an effect is strengthened by consistent findings observed by different persons in different places with different samples.
Specificity (of the association)	When there is a very specific population at a specific site with a disease and there is no other likely explanation, causation is likely. The more specific the association between a factor and an effect, the bigger the probability of a causal relationship.
Temporality (temporal relationship of the association)	The cause has to occur before the effect. If there is an expected delay between the cause and expected effect, then the effect must occur after that delay.
Biological gradient (or dose-response curve)	The greater the exposure, the greater the incidence of the effect. In some cases, just having the factor present can trigger the effect. In other cases, an inverse proportion can be found meaning that greater exposure leads to lower incidence.
Plausibility (is the suspected causation biologically plausible?)	A plausible mechanism between the cause and the effect is helpful, however knowledge of the mechanism is limited by current knowledge.
Coherence	The likelihood of an effect increases when there is coherence between epidemiological and laboratory findings. It is important to know that Hill noted "... lack of such [laboratory] evidence cannot nullify the epidemiological effect on associations".
Experiment	Occasionally it is possible to appeal to experimental or semi-experimental evidence.
Analogy	The effect of similar factors may be considered.

It is important to recognize, however, that associations that do show a trend in disease frequency with increasing levels of exposure are not necessarily causal. For example, confounding can result in a relation between a non-causal risk factor and disease if the confounding factor itself demonstrates a biological gradient in its relation with disease (Rothman & Greenland, 2005).

Some studies have examined industrial wind turbine noise and dose-response relationships for a variety of different outcomes. For example, one study found that noise levels of wind turbines have a dose-response relationship with annoyance. A significantly larger proportion of survey respondents (36%) in the south of Sweden became ‘very annoyed’ with wind turbines at noise levels above 40 dB compared to lower noise levels, such as 32.5-35 dB (8%) (Pedersen & Persson-Waye, 2004). Similarly, Bakker et al. (2012) conducted a study to examine the relation between exposure to the sound of wind turbines and annoyance, self-reported sleep disturbance and psychological distress of people that live near wind turbines. A dose–response relationship was found between emission levels of wind turbine sound and self reported noise annoyance. Another study that used distance as a proxy measure for dose found that participants living closer to industrial wind turbines had worse sleep, were sleepier during the day, and had worse SF-36 mental component scores compared to those living further away from industrial wind turbines. Moreover, significant dose-response relationships were found between PSQI, Epworth Sleepiness Score, SF-36 Mental Component Score and log distance to the nearest industrial wind turbine after controlling for gender, age and household clustering (Nissenbaum et al., 2012).

CHAPTER 3 - METHODS

3.1 Study Area and Participants

Eight wind farms in Ontario were selected for analysis and are shown in Figure 3. For this study, a wind farm was defined as a collection of at least ten industrial wind turbines situated in the same location (Rowlands & Jernigan, 2008). The largest wind

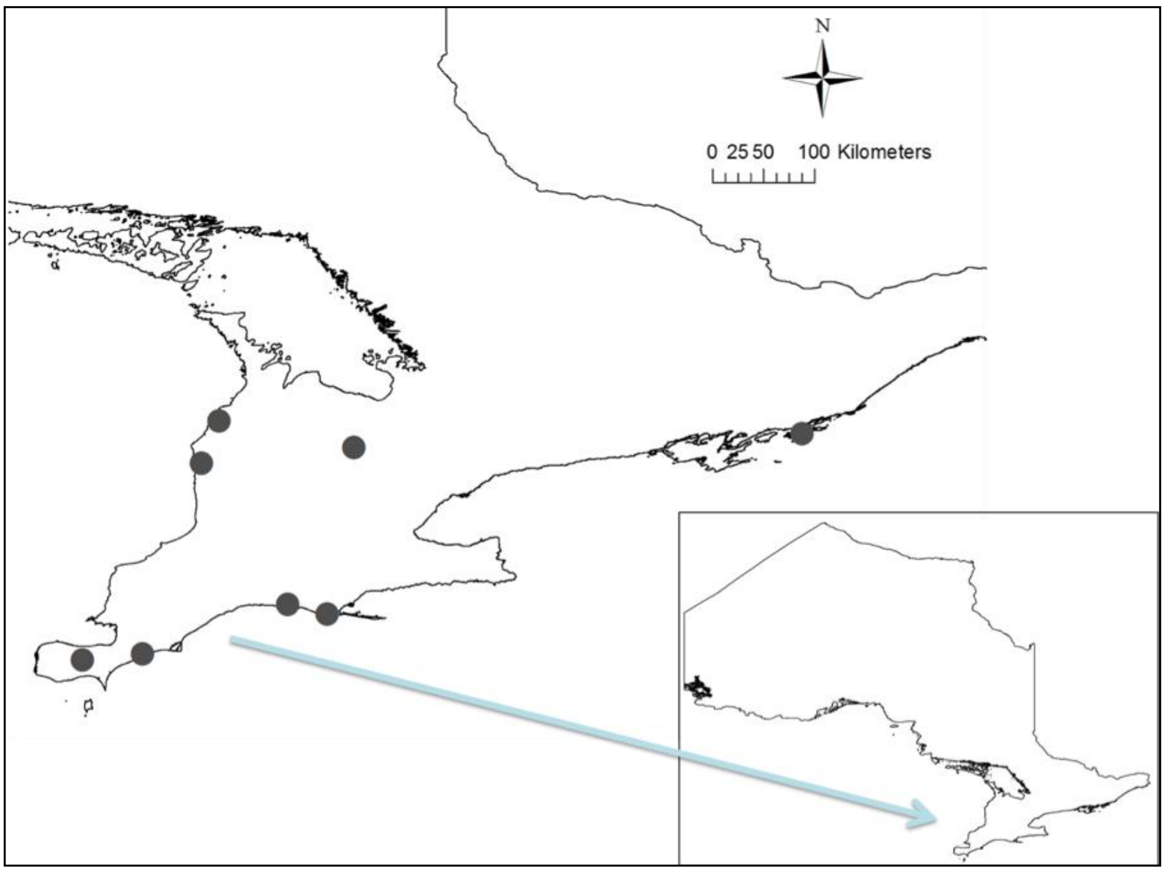

FIGURE 3: ***Eight Wind Farm Communities Analyzed in Ontario. Wind farm sites are shown in grey. The province of Ontario is shown (inset). (Quick et al., submitted).***

farm in each county in Ontario (that has a wind farm) was chosen excluding two wind farms (Prince Wind Power Project [Phase 1 and Phase 2] and Greenwich Wind Farm) because they are located in very remote areas with low population densities. Wind farms that consist of more than one phase or have two separate parts were considered as one wind farm in the selection process (i.e. Melancthon Phase 1 and Melancthon Phase 2; Comber East Wind Project and Comber West Wind Project; and Frogmore Wind Project, Cultus Wind Project, and Clear Creek Wind Farm). Wind farms selected for this study are outlined in Table 2. Individual wind turbine locations were mapped (see Figure 4) by University of Waterloo Researchers using Google Earth, coordinate lists, shapefiles, and by translating data from other maps. Overall, 1,420 wind turbine locations were mapped from 56 wind farms in Ontario (Christidis & Law, 2013). The wind turbine locations from the selected eight wind farms were transferred into ArcGIS 10.1 for analysis (Transverse Mercator Projection was used).

Table 2: Selected Wind Farms for Study

County	Wind Farm	Number of Wind Turbines	Turbines / Total Installed Capacity
Bruce	Enbridge Ontario Wind Farm	110	110 x Vestas 1.65MW (V-82) / 181.5000 (MW)
Chatham-Kent	Raleigh Wind Power Partnership	52	52 x General Electric 1.5MW / 78.0000 (MW)
Dufferin	Melancthon Phase I	45	45 x 1.5 MW GE / 67.5000 (MW)
	Melancthon Phase II	88	88 x GE Energy 1.5 MW turbines / 132.0000 (MW)
Elgin	Erie Shores Wind Farm	66	66 x GE 1.5 MW / 99.0000 (MW)
Essex	Comber East Wind Project	36	Siemens 2.3-MW SWT-2.3-101 x 36 / 82.8000 (MW)
	Comber West Wind Project	36	Siemens 2.3-MW SWT-2.3-101 x 36 / 82.8000 (MW)
Frontenac	Wolfe Island EcoPower Centre	86	86 Siemens 2.3 MW Wind Turbines / 197.8000 (MW)
Huron	Kingsbridge I Wind Power Project	22	22 x Vestas 1.8 MW / 39.6000 (MW)
Norfolk	Frogmore Wind Project	18	6 x Vestas V82 1.65 MW / 9.9000 (MW)
	Cultus Wind Project		6 x Vestas V82 1.65 MW / 9.9000 (MW)
	Clear Creek Wind Farm		6 x Vestas 1.65 MW / 9.9000 (MW)

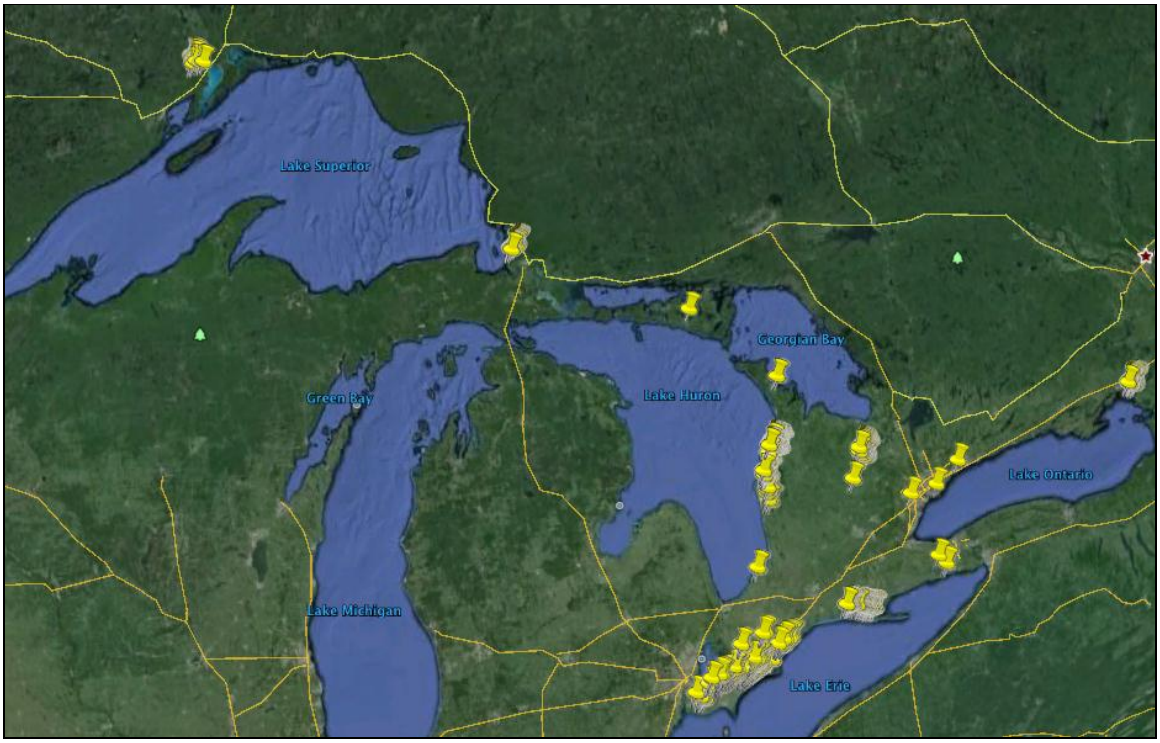

Figure 4: ***Wind Turbine Locations Mapped in Ontario***

ArcGIS 10.1 was used to determine which residences would receive the survey. Within each Canada Post postal code there are several delivery routes that are available online and mailings can be targeted at this level. Residents in the eight counties living within Canada Post's postal codes (and corresponding delivery routes) that contained greater than five industrial wind turbines were selected as study participants (see Figure 5 and Figure 6 below). Canada Post's Business and Residential Counts and Maps were used to determine the 'number of residences' (i.e. sum of houses, apartments and farms) on each delivery route (see Table 3 below). The survey was sent to 4,876 residences (out of 5,658 total residences) located near industrial wind turbines.

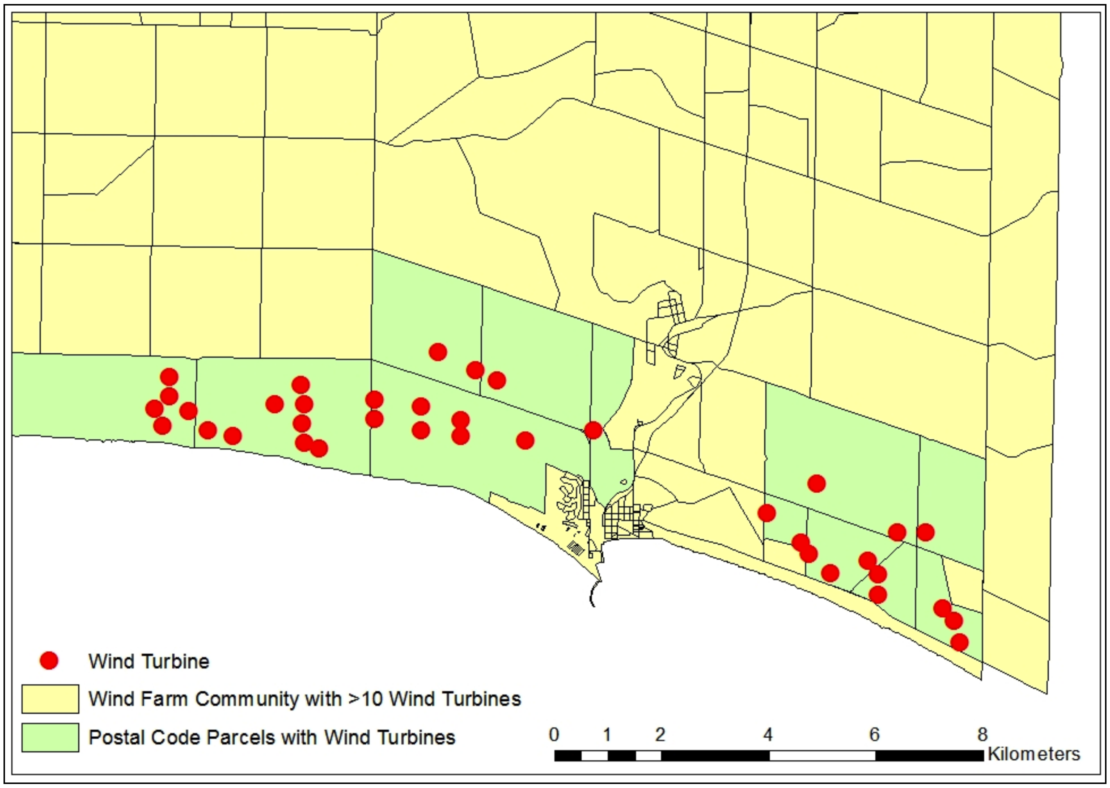

Figure 5: ***Map Showing Parcels of Land within Postal Codes that Contain Wind Turbines in a Wind Farm Community with >10 Industrial Wind Turbines***

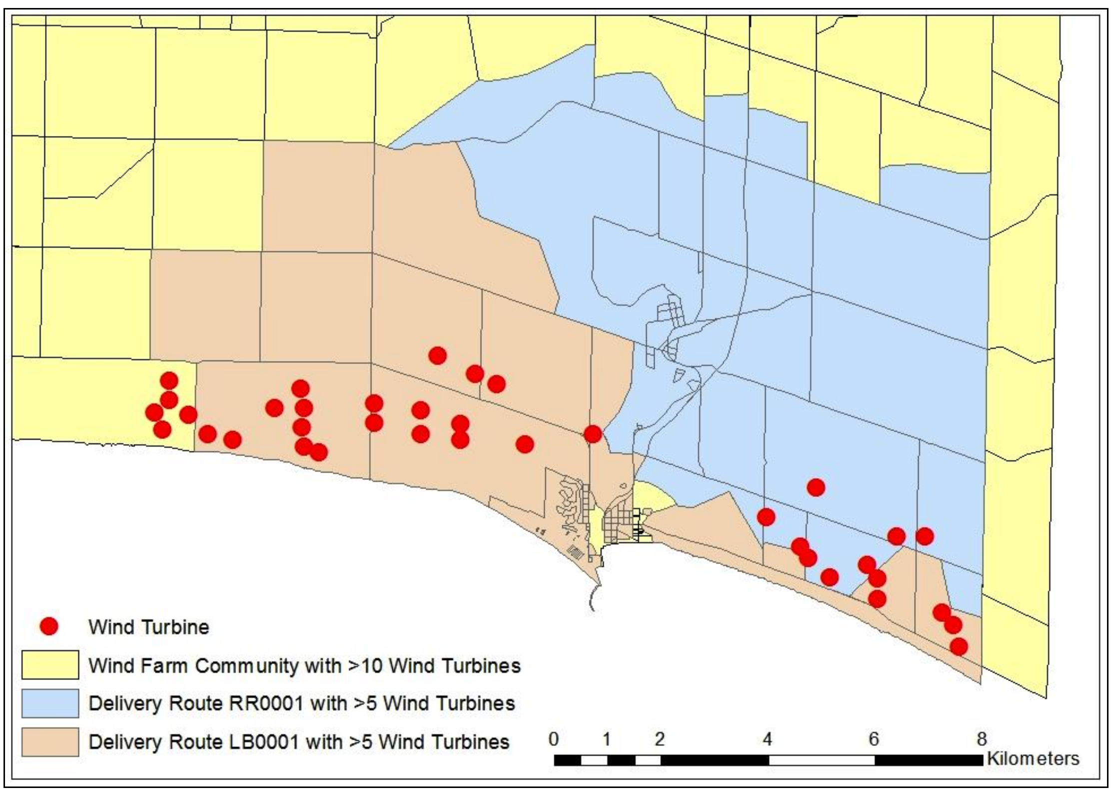

Figure 6: ***Map Showing Delivery Routes with >5 Industrial Wind Turbines***

Table 3: Total Residential Counts for the Study Taken from Canada Post's Business and Residential Counts and Maps

Wind Farm	Postal Code	Post Office	Delivery Route	Houses	Apartments	Farms	Number of Residences
Enbridge Ontario Wind Farm	N0G2N0	Paisley	LB0001	472	0	0	472
	N0G2T0	Tiverton	LB0001	300	37	5	342
	N0H0A0[1]	Port Elgin/Saugeen Shores	LB0002	13	1	0	14
						TOTAL	**828**
Raleigh Wind Power Partnership	N0P1G0	Charing Cross	LB0001	123	1	4	**128**
	N0P1W0	Merlin	LB0001	271	0	0	**271**
		Port Alma	LB0001	16	0	0	**16**
						TOTAL	**415**
Melancthon Phase I and II	L0N1J0[2]	Horning Mills	RR0003	54	0	1	**55**
		Mansfield	RR0003	208	0	21	**229**
		Shelburne	RR0003	219	0	21	**240**
	L0N1S0	Honeywood	LB0001	61	0	5	**66**
		Shelburne	LB0001	219	0	0	**219**
	L0N1S9[2]	Shelburne	RR0006	125	0	10	**135**
						TOTAL	**944**
Erie Shores Wind Farm	N0J1T0	Port Burwell	LB0001	301	0	2	**303**
	N0J1Z0[3]	Vienna	RR0001	367	19	37	**423**
						TOTAL	**726**
Comber East and West Wind Project	N0P1J0	Comber	LB0001	228	15	10	**253**
	N0P2J0	Staples	RR0001	31	0	90	**121**
	N0R1R0[4]	Ruscom Station	RR0001	141	0	21	**162**
		St. Joachim	RR0001	233	0	18	**251**
	N0R1V0	South Woodslee	RR0001	324	9	102	**435**
						TOTAL	**1,222**
Wolfe Island EcoPower Centre	K0H2Y0	Wolfe Island	LB0001	141	7	7	**155**
						TOTAL	**155**
Kingsbridge I Wind Power Project	N7A3Y3	Goderich	RR0006	232	0	52	**284**
	N0M1R0	Dungannon	RR0001	177	0	12	**189**
						TOTAL	**473**
Frogmore/ Cultus/Clear Creek	N0E1C0	Clear Creek	RR0001	94	0	19	**113**
						TOTAL	**113**
					OVERALL TOTAL		**4,876**

[1]Used N0H2C0, Saugeen Shores PO [2]Used L0N1S0, Shelburne PO [3]Used N0J1T0, Port Burwell PO [4]Used N0R1S0, St. Joachim PO

A media release (see Appendix A) notifying study participants that a survey would soon be arriving in their mailbox was sent to major media outlets and to the Public Health Unit in each county prior to survey distribution. Surveys, information letters (see

Appendix B) and contact information forms (see Appendix C) were distributed to the study participants (i.e. everyone living in the selected postal code/delivery route) using Canada Post's Unaddressed Admail Service. Postcards (see Appendix D) were sent out a month after survey distribution to remind people to fill out and return their surveys. Reminder postcards were sent in an effort to improve response rates. The study protocol was reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo.

3.2 Health Outcomes

For this cross-sectional study, the 'Quality of Life and Renewable Energy Technologies Study' survey[2] (Christidis et al., submitted) was used to measure the impact of industrial wind turbines on health. The aim of this survey was to capture the unique experiences of residents in communities with renewable energy technologies. The survey was designed to be completed by a random adult (over the age of 18) in the household by asking the adult with the next upcoming birthday to be the respondent. Based on pre-testing, the survey was expected to take approximately 45 minutes to complete.

The survey was a 32 page booklet that consisted of six parts: 1) Renewable Energy in Ontario, 2) Housing and Community, 3) Environmental Stressors, 4) Sleep, 5) Health and Well-Being, and 6) Demographic Information. The survey incorporated validated surveys including the Satisfaction with Life Scale (Diener et al., 1985), SF-12 (Quality Metric, 2013), Pittsburgh Sleep Quality Index (Buysse et al., 1989), and adapted

[2] The 'Quality of Life and Renewable Energy Technologies Study' survey was designed in 2012 by the Renewable Energy Technologies and Health team at the University of Waterloo. The Ontario Research Chair program in Renewable Energy Technologies and Health at the University of Waterloo was established by the Ministry of the Environment and addresses the technological, health, and safety aspects of renewable energy. For more information visit: http://www.orc-reth.uwaterloo.ca/.

questions from the Project WINDFARMperception Study (van den Berg et al., 2008), Schreckenburg Airplane Noise (Schreckenberg et al., 2010), and the Canadian Community Health Survey (Statistics Canada, 2011). The survey also included questions that collected information about annoyance, exposure and demographics. Twenty outcome variables from the survey were examined in this study (see Table 4). The 'Quality of Life and Renewable Energy Technologies Study' survey received ethics clearance through the Office of Research Ethics at the University of Waterloo.

Table 4: Names, Descriptions and Formats of the Outcome Variables

Variable Name	Variable Description	Variable Format
PSQI	The Pittsburgh Sleep Quality Index (PSQI) assesses sleep quality and disturbance over a one month time period.	***Score out of 9*** with 9 being the extreme negative and 1 being the extreme positive.
PSQI_bin	PSQI scores were also categorized into two groups.	***Two groups:*** 'poor sleeper' (≥5) and 'good sleeper' (<5).
PCS	The Physical Component Score (PCS) is from the SF-12 health survey and measures general physical health status.	***Score out of 100*** with 0 being the extreme negative and 100 being the extreme positive.
PCS_bin	The PCS was also categorized into two groups.	***Two groups***: 'below average physical health status' (≤50) and 'above average physical health status' (>50).
MCS	The Mental Component Score (MCS) is from the SF-12 health survey and measures general mental health status.	***Score out of 100*** with 0 being the extreme negative and 100 being the extreme positive.
Depression_bin	The MCS was also categorized into two groups.	***Two groups***: 'at risk for depression' (≤42) and 'not at risk for depression' (>42).
SWLS	The Satisfaction With Life Scale (SWLS) assesses satisfaction with the respondent's life as a whole and is a global measure of life satisfaction.	***Score out of 35***: extremely satisfied (31-35), satisfied (26-30), slightly satisfied (21-25), neutral (20), slightly dissatisfied (15-19), dissatisfied (10-14) and extremely dissatisfied (5-9).
SWLS_bin	The SWLS score was also categorized into two groups.	***Two groups***: 'satisfied' (>20) and 'dissatisfied' (≤20)
WTS_index	Eight questions from the 'Quality of Life and Renewable Energy Technologies Study' survey were combined to create a Wind Turbine Syndrome (WTS) index: headache, irritable, concentration problems, nausea, vertigo, undue tiredness, tinnitus and overall sleep quality. All eight variables were entered	***Score out of 32*** **(i.e. 8×4)** with 32 being the extreme negative and 0 being the extreme positive.

	into the calculation as a 4-point scale (i.e. 1, 2, 3 or 4).	
WTS_bin	WTS_index scores were also categorized into two groups.	***Two groups:*** 'bad' (≥16) and 'good' (<16).
Headache	Headache was scored on a 4-point scale by asking how often the survey respondent had been troubled by the symptom in the last month.	***Scale of 1 to 4***: 'never or seldom' (1), 'about once a month' (2), 'about once a week' (3), and almost daily (4).
Irritable	Irritability was scored on a 4-point scale by asking how often the survey respondent had been troubled by the symptom in the last month.	***Scale of 1 to 4***: 'never or seldom' (1), 'about once a month' (2), 'about once a week' (3), and almost daily (4).
Concentration Problems	Concentration problems was scored on a 4-point scale by asking how often the survey respondent had been troubled by the symptom in the last month.	***Scale of 1 to 4***: 'never or seldom' (1), 'about once a month' (2), 'about once a week' (3), and almost daily (4).
Nausea	Nausea was scored on a 4-point scale by asking how often the survey respondent had been troubled by the symptom in the last month.	***Scale of 1 to 4***: 'never or seldom' (1), 'about once a month' (2), 'about once a week' (3), and almost daily (4).
Vertigo	Vertigo was scored on a 4-point scale by asking how often the survey respondent had been troubled by the symptom in the last month.	***Scale of 1 to 4***: 'never or seldom' (1), 'about once a month' (2), 'about once a week' (3), and almost daily (4).
Vertigo_bin	Vertigo was scored on a 4-point scale by asking how often the survey respondent had been troubled by the symptom in the last month. For analysis, vertigo was categorized into two groups[3].	***Two groups:*** 'have vertigo' (1) and 'do not have vertigo' (0). The *'have vertigo'* group was made up of 'about once a month', 'about once a week' and 'almost daily' responses and the *'do not have vertigo'* group was made up of 'never or seldom' responses.
Undue Tiredness	Undue tiredness was scored on a 4-point scale by asking how often the survey respondent had been troubled by the symptom in the last month.	***Scale of 1 to 4***: 'never or seldom' (1), 'about once a month' (2), 'about once a week' (3), and almost daily (4).
Tinnitus	Tinnitus was scored on a 4-point scale by asking how often the survey respondent had been troubled by the symptom in the last month.	***Scale of 1 to 4***: 'never or seldom' (1), 'about once a month' (2), 'about once a week' (3), and almost daily (4).
Tinnitus_bin	Tinnitus was scored on a 4-point scale by asking how often the survey respondent had been troubled by the symptom in the last month. For analysis, tinnitus was categorized into two groups[4].	***Two groups:*** 'have tinnitus' (1) and 'do not have tinnitus' (0). The *'have tinnitus'* group was made up of 'about once a month', 'about once a week' and 'almost daily' responses and the *'do not have tinnitus'* group was made up of 'never or seldom' responses.

[3] Vertigo was categorized into two groups (i.e. ' have vertigo' and 'do not have vertigo') for analysis due to an overwhelming number of respondents that answered 'never or seldom' (see Appendix E for distribution of vertigo scores).
[4] Tinnitus was categorized into two groups (i.e. ' have tinnitus' and 'do not have tinnitus) for analysis due to an overwhelming number of respondents that answered 'never or seldom' (see Appendix E for distribution of tinnitus scores).

Overall Sleep Quality	Overall sleep quality was scored on a 4-point scale by asking how the survey respondent would rate their sleep quality overall during the past month.	***Scale of 1 to 4***: 'very good' (1), 'fairly good' (2), 'fairly bad' (3), and 'very bad' (4).

3.2.1 Measurement of Quality of Life

The 'Quality of Life and Renewable Energy Technologies Study' survey collected information about quality of life using two different validated questionnaires: the Satisfaction with Life Scale (SWLS) (see Appendix E) and the SF-12v2 Health Survey (see Appendix F). The SWLS assesses satisfaction with the respondent's life as a whole whereas the SF-12v2 Health Survey measures general health status (i.e. physical and mental health) from the respondent's point of view (QualityMetric, 2013).

3.2.1.1 Satisfaction With Life Scale

The SWLS, developed by Ed Diener and colleagues (1985), assesses satisfaction with the respondent's life as a whole and is therefore a global measure of life satisfaction. The SWLS is made up of five items (each scored on a scale of 1-7 depending on the respondent's level of agreement or disagreement) that measure global cognitive judgments of satisfaction with one's life (Diener et al., 1985; Pavot & Diener. 1993). The scores of the five questions are added up and the SWLS is scored based on the following categories: extremely satisfied (31-35), satisfied (26-30), slightly satisfied (21-25), neutral (20), slightly dissatisfied (15-19), dissatisfied (10-14) and extremely dissatisfied (5-9). SWLS was analyzed as a continuous variable. For purposes of this study, two dichotomous categories were also used: 'satisfied' (>20) and 'dissatisfied' (<=20).

One study (Schreckenberg et al., 2010) looked at life satisfaction using a German life satisfaction scale, similar to the SWLS, to assess mental health, health related quality of life, and possibly show confounding stressors.

3.2.1.2 SF-12v2 Health Survey

The SF-12 is a shortened version of the SF-36, which is a widely used and validated assessment of physical and mental health (Villeneuve et al., 2009). The SF-12v2 Health Survey is designed to measure general health status (i.e. physical and mental health) and is especially useful for large population health surveys. The SF-12v2 Health Survey uses 12 questions and is a practical, reliable and valid measure, from the respondent's point of view, of functional health and well being (QualityMetric, 2013). The SF-12 includes eight concepts commonly represented in health surveys: physical functioning, role functioning physical, bodily pain, general health, vitality, social functioning, role functioning emotional, and mental health. The SF-12 is scored so that a high score indicates better physical functioning. The SF-12 scores were calculated using QualityMetric's Health Outcomes Scoring Software 4.5. From the SF-12, a Physical Component Score (PCS) and Mental Component Score (MCS) can be calculated. The PCS and MCS scores have a range of 0 to 100 and are designed to have a mean score of 50 and a standard deviation of 10 in a representative sample of the United States population (QualityMetric, n.d.). Therefore, scores greater than 50 represent above average health status. The PCS and the MCS were analyzed as a continuous variable. For purposes of this study, both the PCS and the MSC were also categorized into two dichotomous groups. A PCS score <=50 was considered 'below average physical health status' and a PCS score >50 was considered 'above average physical health status'. A MCS score <=42 was considered as 'at-risk for depression', which is consistent with other literature, and a MCS score >42 was considered 'not at-risk for depression'. A cut-point of can be used as a preliminary screener to identify those respondents at risk for depression but it is not a diagnostic measure (Saris-Baglama et al., 2009).

Other studies have used the SF-12/SF-36 health related quality of life surveys to assess the impact of environmental stressors (e.g. odour, radio frequency electromagnetic fields, wind turbines, aircraft noise, etc.) on health (Luginaah et al. 2002; Radon et al., 2004; Villeneuve et al., 2009; Schreckenberg et al., 2010; Berg-Beckhoff et al., 2009; Nissenbaum et al., 2012).

3.2.2 Measurement of Sleep Quality

In the 'Quality of Life and Renewable Energy Technologies Study' survey, information about sleep quality was collected using a validated questionnaire, the Pittsburgh Sleep Quality Index (PSQI) (see Appendix H) and other sleep-related questions. When investigating health, many studies examine sleep quality because research has shown that sleep disturbance and the inability to fall asleep can be associated with anxiety and depression, thus leading to a lack of concentration, daytime sleepiness, and impaired performance (Hungin & Close, 2010). The PSQI, developed by Buysse and colleagues (1989), is an effective instrument used to assess sleep quality and disturbance over a one month time period and is a self-rated questionnaire. The PSQI is the survey most frequently used to assess sleep quality because it is recognized as a valid and reliable tool that provides relevant information on sleep quality. Specifically, the PSQI uses 19 individual questions to measure seven domains: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. The sum of the seven components leads to one global score out of 9 that indicates either “poor” or “good” sleep. Scoring is on a 0-3 scale, with 3 being the negative extreme. PSQI was analyzed as a continuous variable. For purposes of this study, two dichotomous categories were also created: ‘poor sleeper’ and ‘good sleeper’ as this is how the PSQI is typically reported (Buysse et al., 1989). A total sum >=5 indicates a ‘poor sleeper’ and a total sum <5 indicates a ‘good sleeper’. PSQI scores were calculated using SAS Software, Version 9.22 (SAS Institute Inc., Cary, NC, USA) and the scoring instructions available from the University of Pittsburgh Sleep Medicine Institute (Buysse et al., 1989).

Other studies have used the PSQI to assess the impact of environmental stressors (e.g. radio frequency electromagnetic fields, WT, aircraft noise, etc.) on sleep quality (Schreckenberg et al., 2010; Berg-Beckhoff et al., 2009; Nissenbaum et al., 2012). Two of these studies dichotomized PSQI scores into two groups with PSQI scores greater than five representing ‘poor sleepers’ (Nissenbaum et al., 2012) or ‘bad sleep quality’ (Schreckenberg et al., 2010).

3.2.3 Measurement of Wind Turbine Syndrome

Pierpont has proposed a syndrome related to living near wind turbines called “Wind Turbine Syndrome” (WTS), which is comprised of a collection of symptoms including: sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic episodes associated with sensations of internal pulsation or quivering which arise while awake or asleep (Pierpont, 2009). In order to assess Pierpont's proposed WTS, eight questions from the 'Quality of Life and Renewable Energy Technologies Study' survey were combined to create a WTS index: headache, irritable, concentration problems, nausea (e.g. upset or uneasy stomach), vertigo (e.g. feel as if the room is spinning), undue tiredness, tinnitus (i.e. ringing in the ears), and overall sleep quality. Each of the eight variables[5] was scored on a scale of 1-4 (with 4 being the extreme negative) and a score out of a maximum 32 (i.e. 8×4) points was determined. WTS index was analyzed as a continuous variable. For purposes of this study, two dichotomous categories were also used with a combined score >=16 considered 'bad'.

3.3 Survey Return

Completed surveys were returned to the University of Waterloo by study participants using Canada Post's Business Reply Mail Service. This service allowed survey participants to mail their survey back to the University of Waterloo at no cost (i.e. postage was included). Surveys were received from February 1st to May 31st, 2013 and members of the Renewable Energy Technologies and Health Team coded and entered the results into Microsoft Excel as surveys were received.

3.4 Distance Analysis

Survey respondents' self-reported addresses (i.e. full street addresses with city and postal codes) were entered into Google Maps to determine the location of each

[5] When calculating the WTS index values, vertigo and tinnitus were not dichotimized but entered into the calculation as a 4-point scale (i.e. 1, 2, 3 or 4) to maintain consistency with the other six variables.

residence (see example in Figure 7). The data were then exported from Google Maps as KML files and transferred to ArcGIS 10.1 (ESRI Corp., Redlands, CA, USA) (see Figure 8), where the KML files were converted to shapefiles using the ‘ArcTool box’ in ArcGIS 10.1 (Transverse Mercator Projection was used). The near (analysis) feature in ArcGIS 10.1 was used to determine the distance from each input feature (i.e. location of survey respondent’s home) to the nearest feature in the near features (i.e. industrial wind turbine location). These calculated distances are the distances that were used for study calculations.

Figure 7: ***Satellite View from Google Maps Showing Location of Survey Respondents’ Residences in a Wind Farm Community***

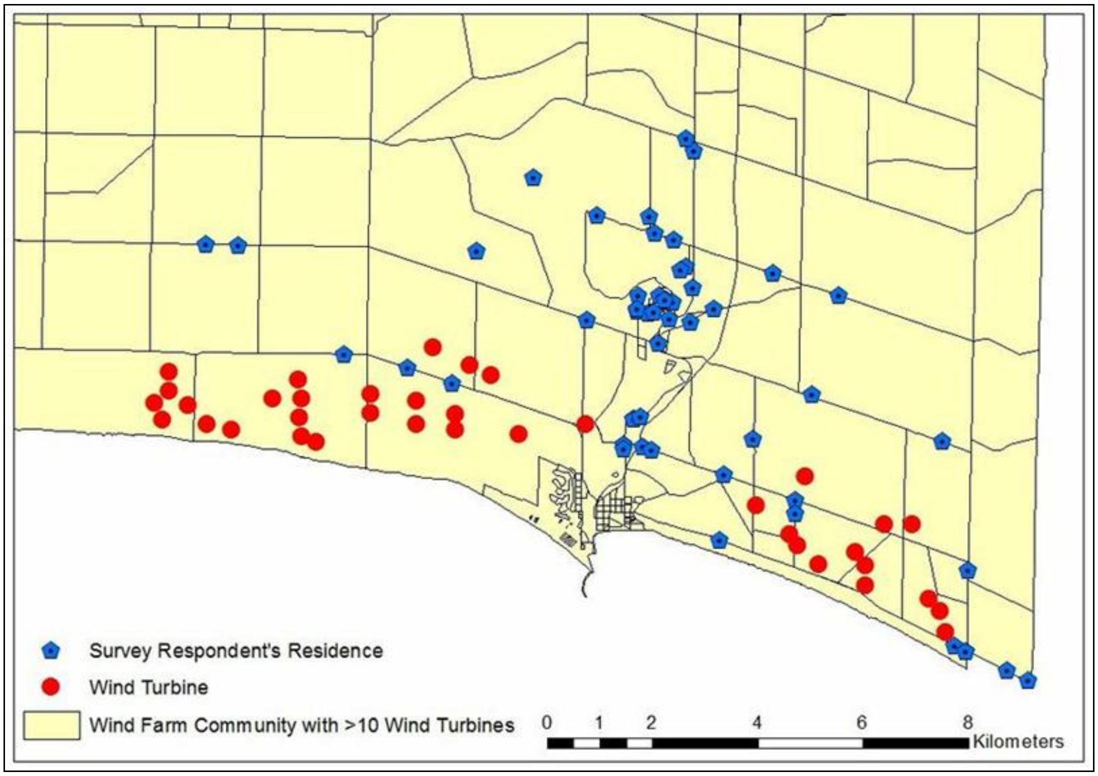

Figure 8: ***Map from ArcGIS Showing Location of Survey Respondents' Residences and Industrial Wind Turbines in a Wind Farm Community***

For descriptive purposes only, the calculated distances were ranked by percentile (1^{st} percentile-100^{th} percentile) and then divided into four quartiles (quartile 1:<25^{th} percentile, quartile 2:<50^{th} percentile, quartile 3:<75^{th} percentile and quartile 4:<100^{th} percentile). From these quartiles, four setback groups were created in order to be able to compare groups of residents living closer to industrial wind turbines (i.e. setback group 1 and setback group 2) to groups of residents living further away from industrial wind turbines (i.e. setback group 3 and setback group 4). In addition, self-reported distances[6] (i.e. the distance survey respondents reported living from a wind farm) were compared to calculated distances to investigate if survey respondents are generally under- or over-

[6] If an exact distance was not reported but rather a range was selected (i.e. 0-1 km, 1-2 km, 2-3 km, 3-4 km, 4-5 km, more than 5 km) the midpoint of the range was used for analysis and for more than 5 km, 5 km was used for analysis.

perceiving the distance they live from a wind farm. In order to compare these two distances, a paired t-test was used.

3.5 Statistical Analysis

All analyses were performed using SAS Software, Version 9.22 for the Windows 7® operating system. Demographics of the sample population were compared to the comparison population (i.e. the Census Subdivision for each county), via a paired t-test, using information from the 2006 and 2011 Canadian Census. The two populations, the sample population and the comparison population, were compared across different variables (i.e. median age, percent male, percent married, median income, and percent with post-secondary education) to see if the respondents were significantly different from the rest of the population. A two-tailed t-test (see Figure 9 below for formula used) was used to test the difference between percent male, percent married, and percent with post-secondary education for the two populations ($H0: p_1 - p_2 = 0$, where p_1 is the proportion from the 'Sample Population' and p_2 the proportion from the 'Comparison Population').

$$t = \frac{p_1 - p_2}{\sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}}}$$

Figure 9: ***Formula Used to Calculate P-Values When Comparing the Sample Population to the Comparison Population***

Descriptive analyses were performed and multiple regression models were run to investigate the effect of the main independent variable of interest (distance to nearest industrial wind turbine) on the various outcome variables. Descriptive statistics, including means and standard deviations were performed on a number of dependent and independent variables including age, sex, time in home, number of industrial wind turbines within 2,000 meters and sleep and health outcomes.

Multiple regression models (see Appendix I) were run using the GENMOD procedure in SAS 9.22 with appropriate response distribution depending on the outcome variable (Binomial, Poisson, or Normal). The GENMOD procedure fits generalized linear models. The class of generalized linear models is an extension of traditional linear models that allows the mean of a population to depend on a linear predictor through a nonlinear link function and allows the response probability distribution to be any member of an exponential family of distributions. Many widely used statistical models are generalized linear models, including classical linear models with normal errors, logistic models for binary data, and log-linear models for multinomial data (SAS Institute Inc., 2008).

When using the GENMOD procedure, age, gender and county were forced into all models. Independent variables assessed included the following: county, distance to industrial wind turbine (both as a categorical and continuous variable); age (continuous variable); gender (categorical variable), satisfaction with life, and number of industrial wind turbines within 2 km (continuous). Dependent variables assessed include the following: PSQI, PSQI_bin, PCS, PCS_bin, MCS, Depression_bin, SWLS, SWLS_bin, WTS_index, WTS__bin, headache, irritable, concentration problems, nausea, vertigo_bin, undue tiredness, tinnitus_bin and overall sleep quality.

To build the models, a step-wise approach was taken starting with a core predictor variable set. First, the following core set of variables were forced into the model: distance (primary predictor variable of interest), age (can be associated with many health outcomes, including sleep), gender (can be associated with many health outcomes, including sleep), and county (attempted to control for project-specific factors such as industrial wind turbine make/model, topography, socio-demographics, etc.). Forcing age, gender and county into each model allowed for consistent adjustment for potential confounding across all models, which is why all three variables were forced into the modeling process (i.e. assessed confounding by forcing them in). Second, two-way interactions were tested. The significance of all two-way interactions among the core variables were tested one at a time (distance×county, distance×age, county×age, etc.). Interactions were kept in the final model only if significant at $P<0.05$. Third, in order to further investigate confounding, additional predictor variables were examined. Specifically, other predictor variables were tested one at a time including SWLS, number of industrial wind turbines within 2,000 meters, and setback group (i.e. setback group 1, setback group 2, and setback group 4). Additional variables were kept in the final model only if significant at $P<0.05$.

Additional analysis included investigating the relationships between all of the outcome variables using the Spearman Rank Order Correlation test. For all statistical tests, a value of $P< 0.05$ was considered statistically significant.

CHAPTER 4 – RESULTS

4.1 Study Participants

The data obtained for use in this study were collected between February 1st and May 31st, 2013. In total there were 412 surveys returned (8.45% response rate); 16 of these survey respondents did not provide their home address. Therefore, 396 surveys were included in the analysis. Overall, the mean age of the survey respondents was 55.33 years (±14.94) and 52.17% were male. The mean number of years that study participants lived in their current residence was 19.12 (±15.29) and, on average, residents had 2.19 (±4.34) industrial wind turbines within 2,000 meters of their residence.

It is important to note that the distribution method used, Canada Post's Unaddressed Admail Service, only allows for delivery of unaddressed mail to people on the "Consumer's Choice" list (i.e. people who do not opt out of receiving unaddressed admail) and not to the "Total Points of Call" list (i.e. all Canadian households where Canada Post delivers mail). This may have resulted in some residents not receiving the survey, however the difference between the number of residents on the "Total Points of Call" list and the "Consumer's Choice" list was not found to be statistically significant (P=0.53) (see Table 5).

Table 5: Comparison of 'Consumer's Choice List' to 'Total Points of Call' List

Wind Farm	Postal Code	Post Office	Delivery Route	Total Residential – Points of Call	Total Residential – Consumer's Choice	Difference[1]
Enbridge Ontario Wind Farm	N0G2N0	Paisley	LB0001	507	472	93.10%
	N0G2T0	Tiverton	LB0001	525	342	65.14%
	N0H0A0[2]	Port Elgin/ Saugeen Shores	LB0002	14	14	100.00%
			TOTAL	**1046**	**828**	**79.16%**
Raleigh Wind	N0P1G0	Charing Cross	LB0001	151	128	84.77%

Power Partnership	N0P1W0	Merlin	LB0001	289	271	93.77%
		Port Alma	LB0001	18	16	88.89%
			TOTAL	**458**	**415**	**90.61%**
Melancthon Phase I and II	L0N1J0[3]	Horning Mills	RR0003	92	55	59.78%
		Mansfield	RR0003	256	229	89.45%
		Shelburne	RR0003	240	240	100.00%
	L0N1S0	Honeywood	LB0001	105	66	62.86%
		Shelburne	LB0001	348	219	62.93%
	L0N1S9[3]	Shelburne	RR0006	135	135	100.00%
			TOTAL	**1176**	**944**	**80.27%**
Erie Shores Wind Farm	N0J1T0	Port Burwell	LB0001	360	303	84.17%
	N0J1Z0[4]	Vienna	RR0001	431	423	98.14%
			TOTAL	**791**	**726**	**91.78%**
Comber East and West Wind Project	N0P1J0	Comber	LB0001	315	253	80.32%
	N0P2J0	Staples	RR0001	124	121	97.58%
	N0R1R0[5]	Ruscom Station	RR0001	167	162	97.01%
		St. Joachim	RR0001	262	251	95.80%
	N0R1V0	South Woodslee	RR0001	448	435	97.10%
			TOTAL	**1316**	**1222**	**92.86%**
Wolfe Island EcoPower Centre	K0H2Y0	Wolfe Island	LB0001	242	155	64.05%
			TOTAL	**242**	**155**	**64.05%**
Kingsbridge I Wind Power Project	N7A3Y3	Goderich	RR0006	313	284	90.73%
	N0M1R0	Dungannon	RR0001	192	189	98.44%
			TOTAL	**505**	**473**	**93.66%**
Frogmore/ Cultus/ Clear Creek	N0E1C0	Clear Creek	RR0001	124	113	91.13%
			TOTAL	**124**	**113**	**91.13%**
					AVERAGE PERCENTAGE DIFFERENCE	**86.75% (P=0.513)**

[1]Differences calculated using data from February 2013 [2]Used N0H2C0, Saugeen Shores PO [3]Used L0N1S0, Shelburne PO [4]Used N0J1T0, Port Burwell PO [5]Used N0R1S0, St. Joachim PO

Response rates for each wind farm community were calculated. The lowest response rate was seen in Bruce County (6.88%) and the highest response rate was seen in Norfolk County (12.39%) (see Appendix J for response rates for each community). A comparison of these Bruce County and Norfolk County is shown in Table 6 below (see Table 13 at the end of the Results section for overall and county-level results).

Table 6: Comparison of Bruce County to Norfolk County

	Bruce	**Norfolk**
Response Rate (%)	6.88	12.39
Sample Size	57	14
Mean Age (±S.D.)	53.41 (±17.42)	44.00 (±16.04)
% Male (n)	63.16 (36)	57.14 (8)
Mean Time in Home[1] (±S.D.)	16.21 (±11.91)	10.29 (±11.38)
Mean # of Industrial Wind Turbines within 2000m(±S.D.)	0.35 (±1.86)	13.21 (±6.42)
Mean PSQI Score (±S.D.)	5.87 (±2.13)	6.21 (±2.12)
% PSQI_bin≥5	71.93	85.71
Mean PCS Score (±S.D.)	49.02 (±9.47)	52.17 (±8.53)
% PCS_bin≤50	43.86	28.57
Mean MCS Score (±S.D.)	50.62 (±9.56)	48.53 (±10.21)
% Depression_bin≤42	14.04	21.43
Mean SWLS Score (±S.D.)	23.37 (±6.50)	24.00 (±6.59)
% SWLS_bin≤20[9]	29.82	28.57
Mean WTS_index Score (±S.D.)	14.39 (±4.85)	14.86 (±5.76)
% WTS_bin≥16	33.33	42.86
Mean Headache Score (±S.D.)	1.70 (±0.97)	1.93 (±0.83)
Mean Irritable Score (±S.D.)	2.07 (±0.90)	2.07 (±0.83)
Mean Concentration Problems Score (±S.D.)	1.98 (±1.01)	2.29 (±1.33)
Mean Nausea Score (±S.D.)	1.49 (±0.74)	1.36 (±0.63)
Mean Vertigo Score (±S.D.)	1.44 (±0.92)	1.43 (±0.76)
% Vertigo_bin=1	21.82	28.57
Mean Undue Tiredness Score (±S.D.)	2.13 (±1.09)	2.29 (±1.27)
Mean Tinnitus Score (±S.D.)	2.09 (±1.31)	1.57 (±1.09)
% Tinnitus_bin=1	46.43	28.57
Mean Overall Sleep Quality Score (±S.D.)	3.05 (±0.49)	3.07 (±0.83)

[1]Years that study participants have lived at current residence

In addition, the overall sample population was compared to the comparison population to see if there was a significant difference between the two groups (see Table 7). The individual county level comparison of the sample population to the comparison population can be found in Appendix L. Median age and median total income were not statistically compared as the data were not comparable because different age groups were used in achieving these medians. Looking at the whole sample population data combined, the median age of the sample population was 13 years older than the median age of the comparison population. There were a greater percentage of males in the sample population (52.17%) compared to the comparison population (49.24%) but this difference was not significant (P=0.24). The sample population had a significantly higher percentage of married people (79.44%) than the comparison population (60.98%) (P<0.005). The sample population also had a significantly higher percentage of people with post-secondary education (58.67%) compared to the comparison population that had 37.06% of the population with post-secondary education (P<0.005). On average, the sample population earned $7111.25 less than the comparison population each year based on median total income.

Table 7: Demographic Comparison Showing the Overall Sample Population Compared to the Comparison Population

Demographic	Sample	Comparison Population	P-Value
# Survey Respondents (# Surveys Sent Out)	396 (4873)	1,021,257	--
Median Age	56	43	--
Sex - Male	52.17%	49.24%	0.24
Married	79.44%	60.98%	<0.005
Median Total Income[ab] ($)	60,000.00	67,111.25	--
Post-Secondary Education	58.67%	37.06%	<0.005

[a]Total income for sample population was calculated by using the mid-point of a range. The total income is the sum of the total incomes received by all household members from all sources, before taxes, in the past 12 months. [b]The total income for the comparison population is the sum of the total incomes of all members of that family. Total income refers to the total money income received from various sources during calendar year 2005 by persons 15 years of age and over.

4.2 Outcome Variables

The mean values for each of the outcome variables (residuals were checked and all assumptions were met) and the p-values for the models are shown in Table 13 (at end of Results section). Overall, for the PSQI, the average score was 5.88 (±2.12) and 65.91% of survey respondents were poor sleepers (i.e. PSQI score≥5). The mean score for the PCS was 48.91 (±10.14) and the mean score for the MCS was 51.74 (±9.41). A total of 43.94% of survey respondents had a below average physical health status (i.e. PCS≤50) and 16.41% were at risk for depression (i.e. MCS≤42). The mean SWLS score was 24.11 (±7.78) and 30.05% of respondents were not satisfied with their life (i.e. SWLS score≤20). On average, the WTS index score was 14.01 (±4.86) with 29.29% of respondents having scores greater than or equal to 16. The average scores for the WTS index variables were: headache [1.87 (±0.99)], irritable [1.92 (±0.87)], concentration problems [1.75 (±0.97)], nausea [1.45 (±0.81)], undue tiredness [2.05 (±1.05)] and overall sleep quality [2.93 (±0.79)]. In terms of vertigo and tinnitus, 22.48% of survey respondents suffered from vertigo (i.e. 'have vertigo') and 35.82% of survey respondents suffered from tinnitus (i.e. 'have tinnitus').

Some of the means found from the scales used in this survey were also compared to comparable health scale scores from the pertinent literature (Table 8). For the SF-12 health scale, the mean PCS (48.91) in this study was slightly higher than a study of Albertans in 2000 (47.60; Johnson & Prickard, 2000) and a study of rural Ontarians living near a hog farm (45.50-47.20; Villeneuve et al., 2000), but lower than a study Germans living near intensive livestock (52.40; Radon et al., 2004). For the MCS component of the SF-12, the study population in this study had a higher mean score than the three comparable populations described above (51.74, versus 51.50, 49.60-51.50, 49.80, respectively). The mean PSQI value (5.88) in this study was lower than the mean PSQI value (7.80) for residents living near wind turbines in the United States (Nissenbaum et al., 2012) and higher than the PSQI values (3.40-4.20) for residents living near an airport in Germany (Schreckenburg et al., 2010).

Table 8: Comparison of Health Scale Scores for Study Population to Comparable Population Health Scale Scores from Other Studies

Scale	Source	Value
Mean SF-12 Physical Component Score (PCS)	Radon et al., 2004	52.40
	Johnson and Pickard, 2000	47.60
	Villeneuve et al., 2009 [1]	45.50-47.20
	Overall Study Population	***48.91***
Mean SF-12 Mental Component Score (MCS)	Radon et al., 2004	49.80
	Villeneuve et al., 2009 [1]	49.60-51.50
	Johnson and Pickard, 2000	51.50
	Overall Study Population	***51.74***
Mean Pittsburgh Sleep Quality Index (PSQI)	Schreckenburg et al., 2010	3.40-4.20
	Nissenbaum et al., 2012 exposed[2] unexposed[3]	 7.80 6.00
	Overall Study Population	***5.88***

[1] Used the SF-36, [2] Lived 375-1,400 meters from a wind turbine, [3] Lived 3,000-6,600 meters from a wind turbine

4.3 Distance Assessment

The mean self-reported distances[7] of survey respondents to wind farms was 2,782 meters ±3,950 meters (range: 0.40-55,000 meters). The mean calculated distance from residence to the closest industrial wind turbine was 4,523 meters ±4,420 meters (range: 316-22,661 meters). The difference between the calculated and perceived distance measurements was found to be statistically significant ($P<0.001$) with survey respondents reporting that they live, on average, 1,741 meters closer to wind farms than they actually do.

Participants in setback group 1 (closest to an industrial wind turbine) resided at a mean distance of 823 meters and had, on average, seven industrial wind turbines within 2,000 meters of their residence. Participants in setback group 4 (furthest from an industrial wind turbine) resided at a mean distance of 10,968 meters and had no industrial wind turbines within 2,000 meters (see Table 9).

[7] In the instances when respondents provided ranges when asked about the distance from their residence to the closest wind farm, midpoints were used.

Table 9: Setback Groups

Setback Group	n	Mean (meters)	Standard Deviation (meters)	Range (meters)
1	98	823	246	316-1,242
2	99	2,037	532	1,262-2,832
3	99	4,161	974	2,849-6,727
4	100	10,968	3,852	6,730-22,661

4.4 Regression Models

Multiple regression models (see Appendix I) were run to assess the relationship between various health outcomes and distance to nearest industrial wind turbine controlling for age, gender and county. Running multiple regression models involved assessing distance to the nearest industrial wind turbine as both distance and ln(distance). In all cases, ln(distance) resulted in improved model fit as determined by overall model fit statistics. No interaction terms were found to be significant. In particular, the ln(distance)×county interaction term was not found to be statistically significant. The models were assessed by looking at confounding, interaction terms and overall model fit (e.g. checking residual plots, examining R-squared values, plotting the data in order to visually assess normality, randomness of errors and possible outliers). The final models used for analysis (and corresponding P-values) can be found in Table 10.

Table 10: Final Models and Corresponding P-Values

Model	P-Value
$PSQI = \ln\_\,dist\; age\; gender\; county\,/$ $dist = normal\; link = ID$	**Distance: 0.01**
	Age: 0.98
	Gender: 0.04
	County: 0.70
$vertigo\_bin = \ln\_\,dist\; age\; gender\; county\,/$ $dist = binomial\; link = \log it$	**Distance: <0.001**
	Age: 0.99
	Gender: 0.26
	County: 0.92
$tinnitis\_bin = \ln\_\,dist\; age\; gender\; county\,/$ $dist = b\; link = ID$	**Distance: 0.08**
	Age: 0.80
	Gender: 0.01
	County: 0.07

The relationship between ln(distance) and PSQI was found to be statistically significant (P=0.01) when controlling for age, gender and county. This relationship shows that as the distance increased (i.e. further away from an industrial wind turbine), PSQI decreased (i.e. sleep improved) in a logarithmic relationship. This relationship is shown in Figure 10.

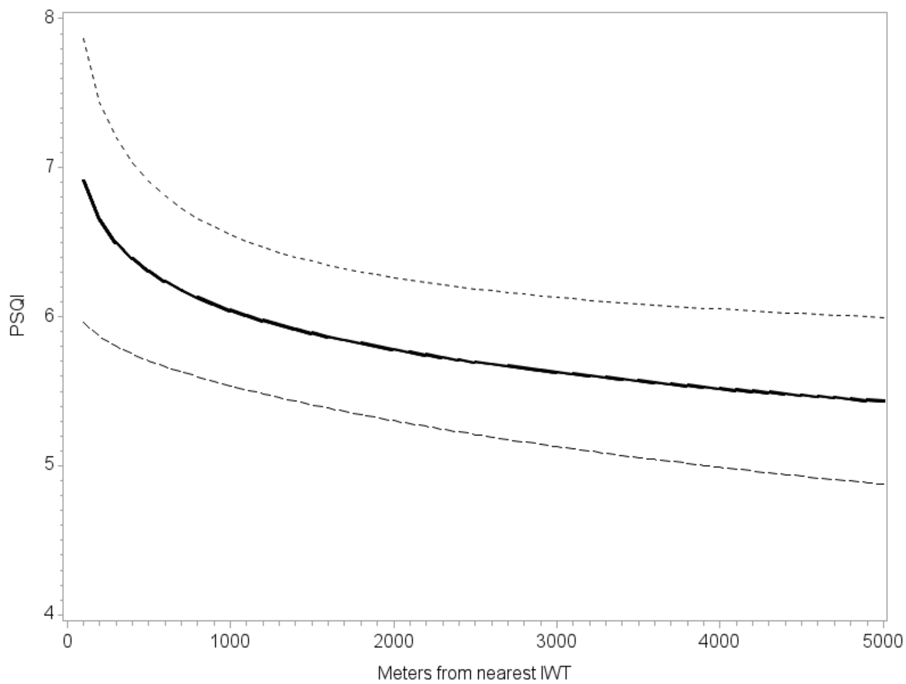

Figure 10: ***PSQI ln_dist Relationship (P=0.01). Graph shows modeled mean and upper and lower 95% confidence intervals***

In addition to assessing the WTS index, which was found to have no significant relationship with ln(distance), each of the eight variables that comprise the WTS index was assessed independently. Among the eight variables, the relationship between vertigo and ln(distance) was statistically significant (P<0.001) when controlling for age, gender, and county. The relationship between tinnitus and ln(distance) approached statistical significance (P=0.08) when controlling for age, gender and county. Both vertigo and tinnitus were worse among participants living closer to industrial wind turbines (See Figure 11 and Figure 12, respectively).

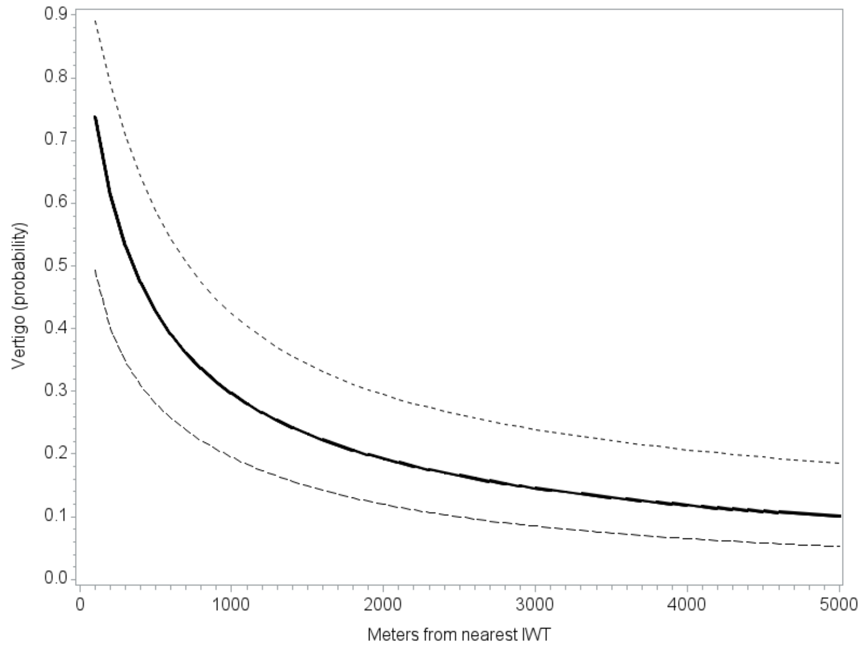

Figure 11: ***Vertigo_bin ln_dist Relationship (P<0.001). Graph shows modeled mean and upper and lower 95% confidence intervals***

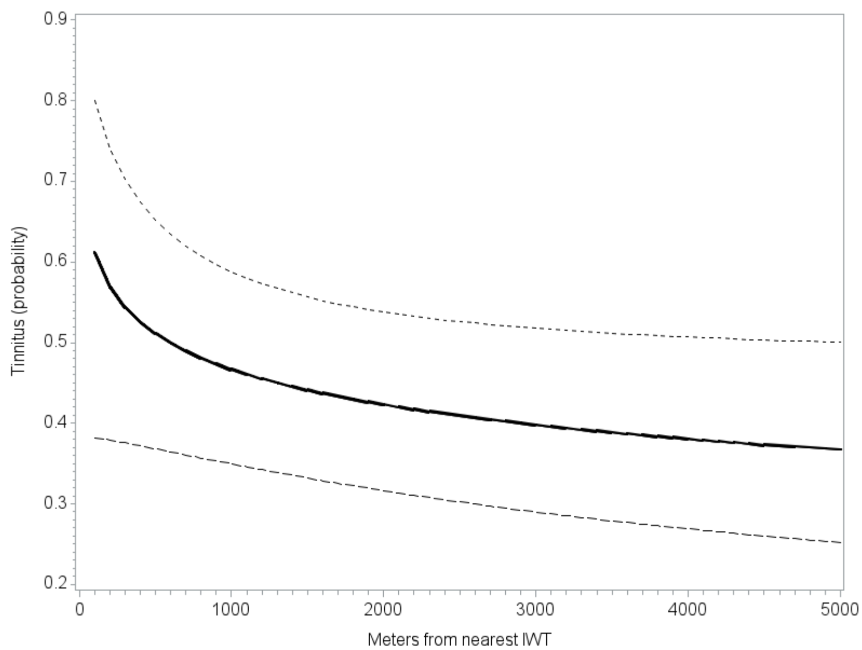

Figure 12: ***Tinnitus_bin ln_dist Relationship (P=0.08). Graph shows modeled mean and upper and lower 95% confidence intervals***

R-squared values and adjusted R-squared values for the relationship between ln(distance) and PSQI, ln(distance) and vertigo and ln(distance) and tinnitus were calculated (see Table 11 below).

Table 11: Calculated R-Squared and Adjusted R-Squared Values for PSQI, Vertigo and Tinnitus

	R-Squared Value	Adjusted R-Squared Value
PSQI	0.08	0.08
Vertigo	0.11	0.16
Tinnitus	0.08	0.11

4.5 Testing Co-Variation between the Outcome Variables

A correlation matrix was run to examine the relationship between all of the variables used for the analysis. Spearman Rank Order Correlation coefficients (r_s) (SAS Institute Inc., 2008) between all the variables can be found in Appendix K.

Spearman Rank Order Correlation coefficients (r_s) between PSQI, vertigo and tinnitus (the three variables that proved to be significant or approach significance) are shown in Table 12. All relationships are positive and statistically significant. The strongest correlation is seen between the variable 'tinnitus' and the variable 'vertigo' (r_s=0.25).

Table 12: Spearman Rank Order Correlation Coefficients between PSQI, Vertigo and Tinnitus

	Vertigo	Tinnitus	PSQI
Vertigo	1	0.25 (P<0.0001)	0.22 (<0.0001)
Tinnitus	0.25 (P<0.0001)	1	0.11 (P=0.04)
PSQI	0.22 (P<0.0001)	0.11 (P=0.04)	1

Table 13: Mean Values for each of the Outcome Variables and the P-Values for the Models

	Overall	Bruce	Chatham-Kent	Dufferin	Elgin	Essex	Frontenac	Huron	Norfolk	Setback Group 1[2]	Setback Group 2[3]	Setback Group 3[4]	Setback Group 4[5]	P-Value for ln_dist
Sample Size	396	57	39	84	55	97	13	37	14	98	99	99	100	--
Mean Age (±S.D.)	55.33 (±14.94)	53.41 (±17.42)	60.64 (±13.33)	54.91 (±13.43)	55.06 (±17.50)	55.66 (±13.25)	55.38 (±16.18)	57.32 (±13.19)	44.00 (±16.04)	51.82 (±14.11)	57.10 (±14.83)	56.01 (±16.04)	56.29 (±14.35)	--
% Male (n)	52.17 (204)	63.16 (36)	46.15 (18)	54.22	44.44 (24)	58.51 (55)	69.23 (9)	43.24 (16)	57.14 (8)	55.67 (43)	49.49 (49)	55.21 (53)	48.48 (48)	--
Mean Time in Home[1] (±S.D.)	19.12 (±15.29)	16.21 (±11.91)	25.99 (±15.84)	18.45 (±17.75)	15.74 (±6.93)	21.24 (±14.77)	17.08 (±15.89)	21.41 (±14.01)	10.29 (±11.38)	18.35 (±14.18)	21.12 (±14.93)	20.60 (±18.12)	16.40 (±13.20)	--
Mean # of Industrial Wind Turbines within 2000m (±S.D.)	2.19 (±4.34)	0.35 (±1.86)	2.79 (±3.08)	0.79 (±2.72)	4.11 (±6.93)	1.57 (±1.55)	4.69 (±4.92)	1.30 (±2.36)	13.21 (±6.42)	7.28 (±5.98)	1.56 (±2.12)	0 (±0)	0 (±0)	--
Mean PSQI Score (±S.D.)	5.88 (±2.12)	5.87 (±2.13)	6.26 (±2.20)	5.72 (±2.27)	5.48 (±2.04)	5.99 (±2.14)	5.70 (±1.64)	5.97 (±2.01)	6.21 (±2.12)	6.24 (±2.27)	6.08 (±2.05)	5.70 (±2.21)	5.48 (±1.91)	**0.01**
% PSQI_bin≥5	65.91	71.93	76.92	58.33	52.73	67.01	61.54	72.97	85.71	69.39	69.70	60.61	64.00	0.26
Mean PCS Score (±S.D.)	48.91 (±10.14)	49.02 (±9.47)	44.21 (±10.47)	49.74 (±9.84)	49.18 (±10.84)	49.52 (±9.49)	50.63 (±9.64)	47.88 (±12.01)	52.17 (±8.53)	49.61 (±10.40)	46.63 (±10.69)	50.11 (±8.88)	49.33 (±10.28)	0.41
% PCS_bin≤50	43.94	43.86	66.67	40.48	40.00	42.27	38.46	45.95	28.57	41.84	55.56	37.37	41.00	0.13
Mean MCS Score (±S.D.)	51.74 (±9.41)	50.62 (±9.56)	50.22 (±12.22)	52.51 (±9.52)	51.45 (±8.32)	52.84 (±9.00)	52.12 (±7.15)	51.95 (±8.71)	48.53 (±10.21)	50.06 (±9.97)	51.40 (±9.96)	53.08 (±7.35)	52.39 (±9.91)	0.20
% Depression_bin ≤42	16.41	14.04	33.33	14.29	16.36	12.37	15.38	16.22	21.43	22.45	17.17	12.12	14.00	0.40
Mean SWLS Score (±S.D.)	24.11 (±7.78)	23.37 (±6.50)	21.84 (±8.62)	23.79 (±8.59)	24.70 (±7.75)	25.39 (±7.50)	23.62 (±7.30)	24.41 (±8.03)	24.00 (±6.59)	25.43 (±6.91)	22.37 (±8.18)	23.90 (±8.29)	24.78 (±7.40)	0.84
% SWLS_bin≤20[9]	30.05	29.82	48.72	32.14	27.27	23.71	23.08	29.73	28.57	22.45	43.43	30.30	24.00	0.79
Mean	14.01	14.39	13.85	13.52	14.50	14.42	12.62	13.14	14.86	14.81	14.51	13.20	13.55	0.24

WTS_index Score (±S.D.)	(±4.86)	(±4.85)	(±4.74)	(±5.50)	(±5.17)	(±4.38)	(±3.20)	(±4.32)	(±5.76)	(±5.28)	(±4.77)	(±4.41)	(±5.07)	
% WTS_bin≥16	29.29	33.33	28.21	23.81	30.91	30.93	23.08	27.03	42.86	36.73	32.32	22.22	26.00	0.23
Mean Headache Score (±S.D.)	1.87 (±0.99)	1.70 (±0.97)	2.00 (±1.01)	1.81 (±0.92)	1.91 (±1.02)	2.02 (±1.05)	1.46 (±0.88)	1.81 (±1.00)	1.93 (±0.83)	1.97 (±1.03)	2.01 (±1.10)	1.79 (±0.87)	1.71 (±0.92)	0.64
Mean Irritable Score (±S.D.)	1.92 (±0.87)	2.07 (±0.90)	1.74 (±0.85)	1.91 (±0.87)	2.04 (±0.91)	1.86 (±0.86)	1.77 (±0.73)	1.92 (±0.92)	2.07 (±0.83)	1.98 (±0.89)	1.92 (±0.85)	1.80 (±0.82)	2.00 (±0.92)	0.99
Mean Concentration Problems Score (±S.D.)	1.75 (±0.97)	1.98 (±1.01)	1.71 (±0.96)	1.64 (±0.96)	1.87 (±0.99)	1.67 (±0.90)	1.42 (±0.90)	1.57 (±0.90)	2.29 (±1.33)	1.86 (±1.05)	1.71 (±0.98)	1.64 (±0.82)	1.78 (±1.02)	0.91
Mean Nausea Score (±S.D.)	1.45 (±0.81)	1.49 (±0.74)	1.38 (±0.75)	1.40 (±0.86)	1.66 (±0.98)	1.53 (±0.82)	1.46 (±0.97)	1.16 (±0.44)	1.36 (±0.63)	1.58 (±0.89)	1.48 (±0.85)	1.33 (±0.64)	1.43 (±0.83)	0.90
Mean Vertigo Score (±S.D.)	1.37 (±0.80)	1.44 (±0.92)	1.44 (±0.72)	1.33 (±0.76)	1.40 (±0.93)	1.40 (±0.82)	1.31 (±0.63)	1.22 (±0.58)	1.43 (±0.76)	1.65 (±0.96)	1.36 (±0.70)	1.40 (±0.83)	1.23 (±0.70)	--
% Vertigo_bin=1	22.48	21.82	30.77	20.99	18.87	24.21	23.08	16.22	28.57	35.79	27.55	14.43	12.37	**<0.001**
Mean Undue Tiredness Score (±S.D.)	2.05 (±1.05)	2.13 (±1.09)	2.13 (±1.17)	2.02 (±1.05)	1.92 (±1.01)	2.08 (±1.04)	2.15 (±0.90)	1.92 (±0.95)	2.29 (±1.27)	2.17 (±1.05)	2.12 (±1.11)	1.98 (±1.04)	1.95 (±0.99)	0.32
Mean Tinnitus Score (±S.D.)	1.79 (±1.18)	2.09 (±1.31)	1.56 (±1.07)	1.83 (±1.22)	1.96 (±1.24)	1.79 (±1.18)	1.46 (±0.78)	1.46 (±0.99)	1.57 (±1.09)	1.82 (±1.15)	1.76 (±1.13)	1.71 (±1.16)	1.86 (±1.25)	--
% Tinnitus_bin=1	35.82	46.43	25.64	35.80	45.28	35.79	30.77	21.62	28.57	42.11	37.76	27.84	35.71	**0.08**
Mean Overall Sleep Quality Score (±S.D.)	2.93 (±0.79)	3.05 (±0.49)	2.92 (±0.76)	2.95 (±0.83)	2.90 (±0.86)	2.83 (±0.81)	3.17 (±0.58)	2.92 (±0.95)	3.07 (±0.83)	2.89 (±0.85)	2.82 (±0.82)	2.96 (±0.73)	3.06 (±0.72)	0.18

[1]Years that study participants have lived at current residence [2]316-1,242 meters from an industrial wind turbine [3]1,262-2,832 meters from an industrial wind turbine [4]2,849-6,727 meters from an industrial wind turbine [5] 6,730-22,661 meters from an industrial wind turbine

CHAPTER 5 – DISCUSSION

The objectives of this study were to examine if there are any self-reported adverse health effects related to mental health, physical health and sleep disturbance from exposure to industrial wind turbines. Residents from eight Ontario wind farm communities that contain greater than ten industrial wind turbines were used for this study. The relationship between PSQI and ln(distance) was found to be statistically significant (P=0.01) when controlling for age, gender and county meaning that as distance increased (move further away from an industrial wind turbine), PSQI decreased (i.e. sleep improved) in a logarithmic relationship. Among the eight WTS index variables, the relationship between vertigo ln(distance) was statistically significant (P<0.001) when controlling for age, gender, and county. Additionally, the relationship between tinnitus and ln(distance) approached statistical significance (P=0.08) when controlling for age, gender and county. Both vertigo and tinnitus were worse among participants living closer to industrial wind turbines. It is important to note that in epidemiological studies, such as this one, there are limitations, such as response rate and potential biases. Study findings suggest that future research should focus on the effects of industrial wind turbine noise on sleep disturbance and symptoms of inner ear problems.

5.1 Study Participants

The response rate was relatively consistent across each of the eight counties, with an overall response rate of 8.45%. The lowest response rate (6.88%) was seen in Bruce County and the highest response rate (12.39%) was seen in Norfolk County. This is interesting as the county with the lowest response rate had the most number of wind turbines (n=110) in this study and the county with the highest response rate had the least number of wind turbines (n=18) in this study. Therefore, we cannot assume that people with more industrial wind turbines around their residence or in their community would be more likely to respond than those with less industrial wind turbines around them.

A demographic comparison was done to compare respondent data overall and for each of the eight wind farm communities (i.e. the study sample) to Statistics Canada census division data for the eight counties (i.e. the comparison populations). Overall, the sample population was older and had a higher percentage of males, but had a lower median total income when compared to Statistics Canada census division data for the eight counties combined. The difference between the sample population and comparison population was statistically significant when comparing marital status, with study participants more likely to be married. The phenomenon that survey respondents are more likely to be married has been described previously (Radler & Ryff, 2010). The difference between the study sample and comparison population was also statistically significant when comparing post-secondary education status, with study participants more likely to have some sort of post-secondary education. When a county level analysis was performed similar results were found. Given these differences between the sample population and the comparison population, it does not appear that the sample population is truly representative of the comparison population. However, gauging sample representativeness is limited due to a lack of community level demographic data. Specifically, the comparison population variables used to check population representativeness come from the county, the larger metropolitan area of which the study community is part. In future studies it will be important to make sure that the sample population is representative of the comparison (or target) population in order to increase the internal validity of the study findings.

5.2 Health Outcomes

The scales used in 'Renewable Energy Technologies and Quality of Life Survey' have been used in studies similar to this study and are validated scales. The mean scores from other studies compared to the mean scores calculated in this study were found to be similar showing that the scale scores in this study are not that different from the scale scores in comparable studies.

The results of this study are consistent with the findings of other studies, which demonstrate a relationship between proximity to industrial wind turbines and adverse health effects (van den Berg et al., 2008; Pedersen et al., 2009; Shepherd et al., 2011; Nissenbaum et al., 2012). Specifically, the significant relationship found between ln(distance) (as a continuous variable) and PSQI (P=0.01) is consistent with findings from a recent study (Nissenbaum et al., 2012). PSQI examines the sleep quality averaged over a period of weeks and scores >=5 represent poor sleep quality. Because of the way the PSQI scoring works, an individual's score will not be significantly affected by occasional disrupted nights (Buyse et al., 1989). Also, because PSQI is a standardized scale used to measure sleep disturbance, it would be hard for people to skew their responses to achieve a certain outcome.

Symptoms associated with industrial wind turbines were tested as an index and no significant relationship was found between distance and WTS index. Each of the eight components that make up the WTS index – headache, irritable, concentration problems, nausea, vertigo, undue tiredness, tinnitus, and overall sleep quality – were then tested separately to see if there was a relationship with ln(distance). The relationship between vertigo and ln(distance) was the only health outcome that proved to be statistically significant ($P<0.001$) when controlling for age, gender, and county. The relationship between tinnitus and ln(distance) approached statistical significance ($P=0.08$) when controlling for age gender and county. Both vertigo and tinnitus were worse among participants living closer to industrial wind turbines.

Statistical analysis demonstrated that the relationships between sleep and distance, vertigo and distance and tinnitus and distance were not affected by county. We had hypothesized that variation across the eight counties might have led to identifying farm-specific factors (number of industrial wind turbines, age of wind farm, distance to industrial wind turbine, community views towards industrial wind turbines, etc.). This could be because there is increased media and communications around wind turbines (especially since there is currently a heightened public perception of industrial wind turbines as a potential health risk) across the province leading to a higher level of connectedness between residents living close to industrial wind turbines. On the contrary, Deignan (2013) states that “differences in risk messages about wind turbines and health between provincial and community newspapers may set the stage for greater or lesser resistance to wind turbines amongst Ontario communities”. Regardless, effective risk communication across the province can help to clarify the nature of disagreements and enable people to make more considered and informed decisions. As a result, understanding and managing risk messages and information related to wind turbines, specifically wind turbines and health, is a significant concern for policymakers.

5.2.1 R-Squared Values for PSQI, Vertigo and Tinnitus

R-squared values and adjusted R-squared values for the three final models – ln(distance) and PSQI, ln(distance) and vertigo and ln(distance) and tinnitus – were 0.08 and 0.08, 0.11 and 0.16, and 0.08 and 0.11, respectively. The calculated R-squared value *is not* dependent on the number of variables in the model, where as, the adjusted R-squared *is* dependent on the number of variable in the model. R-squared is a statistical measure of how close the data are to the fitted regression line. An R-squared value of 0 (i.e. 0%) indicates that the model explains none of the variability of the response data around its mean. On the contrary, an R-squared of 1 (i.e. 100%) indicates that the model explains all the variability of the response data around its mean. Therefore, the higher the R-squared value, the better the model fits the data.

It is important to note that in observational epidemiological studies, particularly those with self-assessment/self-reporting and "soft" outcomes, such as this study; the R-squared values are typically low (usually below 10%) (Stradling & Crosby, 1991; Short et al., n.d.; Acebo et al., 2005; El-Sheikh et al., 2013). In infectious disease or toxicological studies (i.e. studies that do not try to predict human behaviour), the R-squared value is generally much higher (Minitab Inc., 2014). The calculated R-squared values mentioned above show that, although two variables (PSQI and vertigo) are significantly associated with distance to industrial wind turbine and one variable (tinnitus) approaches significance, the models should not be used to predict future outcomes at the individual level because the R-squared values are all less than 20%.

5.2.2 Co-Variation

The Spearman Rank Order Correlation coefficients show that PSQI was positively correlated with vertigo ($P<0.0001$) and tinnitus ($P=0.04$) and that vertigo was positively correlated with tinnitus ($P<0.0001$). This means that although a resident is more likely to suffer from vertigo and tinnitus if they have poor sleep quality, it does not mean that they will for sure suffer from vertigo and tinnitus. Similarly, it means that although a resident is more likely to suffer from tinnitus is they have vertigo it does not mean that they will for sure suffer from tinnitus.

5.3 Distance Assessment

The mean self-reported perceived distance of survey respondent's residence to wind farms was 2,782 meters. The mean calculated distance from residence to the closest industrial wind turbine was 4,523 meters. It is important to note that the calculated distance is an approximate measure because Google Maps was used to geocode residents' self-reported addresses and Google Maps has its limitations (e.g. Google Maps gives an approximate location of the address(es)) related to geocoding, especially in rural locations. The difference between the self-reported distances and the calculated distances was found to be statistically significant ($P<0.001$). Therefore, residents reported living closer to wind turbines than they actually live (i.e. the perceived distance from residence to closest wind turbine is greater than the calculated distance from residence to closest wind turbine). This is interesting as it demonstrates that study participants think they live closer to industrial wind turbines that they actually do. This may impact setback decisions and health perceptions because if people think they are living closer to wind farms, they may also think that their ‘dose’ (i.e. exposure to wind turbines) is higher than it actually is.

5.4 Low Frequency Noise and the Inner Ear

Industrial wind turbines emit noise and have a low frequency component. As discussed earlier in the introduction section, the noise produced by industrial wind turbines is impulsive in nature and is described as ‘swooshing’ or ‘thumping’ (van den Berg et al., 2012). Although industrial wind turbines generate a broadband (i.e. cover many frequencies) low level sound, they have easily perceived modulations caused by the differences in wind velocity at different heights, which can increase and decrease the sound power level with the pace of rotation (van den Berg, 2006). Furthermore, since industrial wind turbines are mainly placed in rural areas with low ambient sound pressure levels, intrusion of sound is most likely to be high in these relatively quiet areas (Pedersen & Persson-Waye, 2008).

The effect on sleep from noise emitted by industrial wind turbines has the potential to lead to various health effects. For example, previous studies have shown associations between sleep disturbance and depression and anxiety (Taylor et al., 2005; Alfano et al., 2007; Spoormaker & Van Den Bout, 2005). Taylor et al. (2005) suggest that insomnia is a risk factor for poor mental and physical health. They found that people with insomnia had greater depression and anxiety levels than people not having insomnia and were 9.82 and 17.35 times as likely to have clinically significant depression and anxiety, respectively. Other studies have suggested insomnia and sleep quality are bidirectionally related to anxiety and depression (Jansson-Frojmark & Lindblom, 2008;

Morphy et al, 2007). Due to the complex associations between sleep disturbance and depression, the etiological relationship between these problems remains unclear.

It is also important to look at how mechanisms other than sleep disruption could affect people's health and well-being. For example, a mechanism has recently been proposed whereby infrasound from industrial wind turbines could affect the cochlea and cause many of the symptoms that people describe (Salt & Hullar, 2010). In other studies, low frequency noise has been shown to contribute to the symptoms of "Sick Building Syndrome" (e.g. headache, irritability, and lethargy), which has similarities to "Wind Turbine Syndrome" symptoms (Niven et al., 2000; Persson et al., 1997). Salt and Hullar (2010) performed a study that looked at possible ways that low frequency sounds (audible or non-audible levels) could influence the function of the ear. They reported that there are abnormal states when inner ear components (such as the outer hair cells) can become hypersensitive to infrasound. The way that the inner ear responds to infrasound can, in most cases, be considered normal, however, these responses could be associated with unfamiliar sensations or subtle changes in physiology. This suggests that the infrasound produced from industrial wind turbines could influence the physiology of the ear, thus resulting in changes that disturb the individual (Salt & Hullar, 2010). Therefore, the associations between ln(distance) and PSQI, ln(distance) and vertigo and ln(distance) and tinnitus could also be a result of the low frequency noise that industrial wind turbines produce.

5.5 Limitations

There are several limitations to the research findings presented in this thesis mainly related to survey distribution method and response rate, potential biases, and mapping of rural addresses and industrial wind turbine locations. These limitations are discussed in detail in the following sections.

5.5.1 Survey Distribution Method and Response Rate

A limitation of this study involved the survey distribution method used. Canada Post Unaddressed Admail Service only delivers unaddressed mail to people on the "Consumer's Choice" list (i.e. people who do not opt out of receiving Unaddressed Admail) and not to the "Total Points of Call" list (i.e. all Canadian households where Canada Post delivers mail). This may result in some residents not receiving the survey, however, the difference between the number of residents on the "Total Points of Call" list and the "Consumer's Choice" list was not found to be statistically significant (P=0.531).

Furthermore, by using Canada Post's Unaddressed Admail Service surveys were sent to residences but they were not addressed to any one resident or residence specifically. Therefore, there is no way of knowing whether each household actually received the survey or, if they did receive the survey, there is no way of knowing if they opened it. As a result, Canada Post's Unaddressed Admail Service allowed us to deliver the survey to a large number of people over large geographic areas but response rates may have been lower due to the use of the Unaddressed Admail Service. If the survey distribution method did affect the response rate we can assume this impact would be consistent across all eight counties in the study as the same distribution method was used in each county.

An overall response rate of 8.45% means that this study may have failed to capture the self-reported health effects of many people within our study population resulting in poor sample representativeness, thus decreasing internal validity. For example, it may be possible that a higher proportion of non-respondents living closer to the industrial wind turbines truly had adverse health effects as compared to those in the study sample and the findings would be biased in the direction of failing to observe any relationship between distance from the industrial wind turbines and health effects. Alternatively, it may be possible that non-respondents were more likely to not be experiencing symptoms or adverse health effects as compared to those who completed the survey. Thus the sample would have overrepresented those with symptoms. Given that individuals living closer wind farms are likely more aware of the existence of industrial wind turbines than those further away, they may have been more likely to have symptoms and responded to the survey. Overall, this means that the associations between distance to closest industrial wind turbine and certain health outcomes may have been underestimated or overestimated but there is no way of knowing the effect that the low response rate had on these associations.

5.5.2 Potential Biases

All studies have built-in bias (i.e. systematic error) and bias is especially important to discuss in a study such as this one. Bias is a form of systematic error that can affect scientific investigations, distort the measurement process and undermine the internal validity of research. Internal validity concerns the validity of inferences about the target population[8] using information from the study population[9]. Therefore, the term "internal" relates to inferences that do not proceed beyond the target population of restricted interest (Kleinbaum et al., 1982).

Unfortunately, it is difficult or even impossible to completely eliminate bias, which is the main challenge when designing research studies. It is important for investigators, editors, and readers to be able to judge how the residual effects of bias might affect results in order to limit misinterpretation and misuse of data (Sica, 2006; Grimes & Schulz, 2002; Schoenbach et al., 2001). Although it is difficult to obtain sufficient information to precisely quantify the extent (or size) of the bias in most epidemiological studies, it may sometimes be possible to determine the direction of the bias. Here, 'direction' refers to whether the effect actually being estimated (Θ^0) either exceeds or is less than the true effect (Θ). The direction of the bias can be classified as *toward the null* or *away from the null*. The direction of the bias is defined to be *toward the null* if Θ^0 is closer than Θ to the null value of the effect measure. If the bias *is toward the null* then the observed effect in the data appears to be weaker than it really is in the target population. The direction of the bias is defined to be *away from the null* if Θ^0 is farther than Θ from the null value of the effect measure. Therefore, if the bias is *away from the null* then the observed effect in the data appears to be stronger than it really is in the target population.

[8] The 'target population'is the population for which the study intends to make estimates for (i.e. the people we believe we are studying) (Kleinbaum et al., 1982).
[9] The 'study population' or 'sample population' consists of a group of participants whose data the study has collected and analyzed (Kleinbaum et al., 1982).

There are three major classes of bias that epidemiologists generally refer to: selection bias, information bias, and confounding bias (Kleinbaum et al., 1982). It is likely that the associations between distance to closest industrial wind turbine and various health outcomes may have been affected as a result of certain types of biases, namely selection bias and information bias.

One source of selection bias in this study could have been survivor bias, in which residents severely affected by industrial wind turbines may have moved away before the survey was distributed, meaning that the community may be comprised of residents less impacted by industrial wind turbines. Therefore if the people that suffered the most from exposure to industrial wind turbines were overlooked in our study, we would expect that the observed measure of effect would have been weaker compared to the true measure of effect.

Another source of selection bias in this study could have been non-response bias due to various groups that are against the research being conducted. For example, anti-wind turbine blogs and websites reported negative things about the 'Renewable Energy Technologies and Quality of Life Survey' and the study in general. One blog member wrote "I advise you do not participate in the University of Waterloo Study…This research is unethical". Another blog member wrote "Is this a health study, or a sick joke???". Comments and opinions such as these may have discouraged residents to complete the survey or may have altered the way people responded, particularly those who frequent these blogs. However, it is important to note that there were blogs, websites and newspaper articles that reported positive things about the survey and encouraged people to fill out and return the survey. Therefore, this potential source of selection bias could have caused the association to go toward the null (if the most affected people did not complete the survey) or it could have caused the associations to go away from the null (if the least affected people did not complete the survey or only the most affected people completed the survey).

Furthermore, in the past there has been discussion about non-disclosure agreements that may exist, meaning that residents who have installed industrial wind turbines have signed a contract with industrial wind turbine companies to ensure that they do not take part in research studies or media interviews. After a review of public documents and discussions with residents with industrial wind turbines on their land, nearby neighbours, and a lawyer, Walker (2012) concluded that agreements (between industrial wind turbine companies and residents with industrial wind turbines on their land) could not stop people from speaking out against wind farms and their impacts. It could be that many people who have signed contracts with industrial wind turbine companies perceive these contracts as “gag-orders” (Walker, 2012). Another idea is that economic benefits from industrial wind turbine developments may reduce the likelihood that a person will report reduced quality of life or adverse health effects. If non-response bias really did occur, there may have been many people not captured in our study results, meaning that the observed measure of effect could have been weaker or stronger compared to the true measure of effect. However, we do not know who and why people did not respond so it is very difficult to determine the direction of the bias.

One source of information bias is a misunderstanding of questions by a subject completing a questionnaire (i.e. misclassification) or the inability or unwillingness to give the corrective response. For example, people who support industrial wind turbine developments or those who do not support industrial wind turbine developments may have skewed their answers to represent their subjective feelings and not actually what they are experiencing. Moreover, the cross-sectional survey used is this study assessed aspects of health, quality of life, and sleep through self-reported, subjective measures. Health outcomes like the ones that were measured in this study (e.g. tinnitus, sleep, and vertigo) are difficult to measure accurately especially when the way we are measuring whether someone is affected is by asking them through a survey. Specifically, differential misclassification may have occurred if the probability of being misclassified differed across the eight communities of study subjects. These types of information biases mentioned above may have resulted in the observed measure of effect being weaker or stronger than the true measure of effect.

Therefore, all these sources of bias undermine the internal validity of this study meaning that is it difficult to make inferences about the target population based on the results from the study population and therefore it makes it difficult to conclude that an association does truly exists between distance to closest industrial wind turbine and certain health outcomes.

5.5.3 Mapping

Another limitation of this study involved measuring distances from residences to closest industrial wind turbines. Specifically, the locations of residences may not be exact (due to restrictions in geocoding rural addresses) and thus the distances only provide an estimate. Google Maps was used to geocode the addresses. For public health surveillance and spatial epidemiology studies, such as this research, geocoding is increasingly being used (Kumar et al., 2012). Google Maps is a geocoding tool that acts as an address approximation service, not as a standardization or verification service. Although Google Maps does an excellent job at address approximation, it is important to realize that it is still gives an approximate location of the address(es) entered into Google Maps.

Numerous studies have evaluated and compared various geocoding methods. One study performed by University of Southern California's GIS Research Laboratory conducted a comprehensive evaluation of eight frequently used geocoding software packages: Centrus, Geolytics, ESRI ArcGIS, Geocoder.us, Google Earth, Google Maps API, Yahoo API, and open source USC Geocoding Platforms (Swift et al., 2008; Kumar et al., 2012). This study found that each of these geocoding software packages has strengths and weaknesses and, in general, no package performed significantly better or worse than the others (Kumar et al., 2012). Therefore, due to accessibility and resources, it was decided that Google Maps would be used for this research project. The distance measurements that were calculated using Google Maps may be inaccurate (and we cannot predict these inaccuracies), meaning that these distance measurements are a source of random error in this study.

Similar to the accuracy of residence locations, another factor to consider is the accuracy of the industrial wind turbine locations. A significant limitation of the wind turbine mapping is that the wind turbine locations may vary in accuracy depending on the mapping method used. Future studies wanting to use these wind turbine locations for research are encouraged to verify the accuracy through site visits or further data collection. The limitations related to accuracy of residence locations and accuracy of industrial wind turbine locations are important to note, especially for environmental health and risk applications similar to this study, where the distance between a home and an industrial wind turbine must be accurate to assess a potential dose-response relationship (Christidis & Law, 2013). Additionally, when calculating the exposure variable (i.e. distance to closest industrial wind turbine), we only took into account the closest wind turbine. The issue in only using distance to the closest industrial wind turbine as an exposure variable is that it does not take the number of industrial wind turbines around each residence or the size, power, make, and model of each industrial wind turbine into account.

CHAPTER 6 – CONCLUSION

Study findings suggest that industrial wind turbines could have an impact on health. Using a sample of rural Ontario residents (although it was unrepresentative of the target population), this study was successful in exploring the quality of life (both physical and mental health) and sleep disturbance of residents living in the vicinity of industrial wind turbines. It is important to note that there are still many questions still to be answered before firm conclusions can be drawn.

Statistically significant relationships were found between ln(distance) and PSQI and ln(distance) and self-reported vertigo, and the relationship between ln(distance) and self-reported tinnitus approached statistical significance. Based on the findings of this study it is recommended that further studies be carried out to examine the effects of low-level stressors, such as industrial wind turbine noise, on health. Specifically, study findings suggest that future research should focus on the effects of industrial wind turbine noise on sleep disturbance and symptoms of inner ear problems. Although this research did find a relationship between various health outcomes and how far someone lives from an industrial wind turbine, it is important to remember that there are limitations to these conclusions. Also, this study is just one piece of a much larger puzzle, and without all of those other pieces it is hard to determine whether there is a causal relationship.

Further studies are needed that include a larger number of respondents, especially at the upper end of the dose curve (i.e. the people living closest to industrial wind turbines) before firm conclusions can be made. Another recommendation for further studies is to try to increase response rates by engaging and educating concerned residents and communities so that they can understand why they need to participate in these types of research studies. By educating these groups, it is more likely that people will want to respond to future surveys, or participate in future studies, thus increasing response rates and sample representativeness, reducing non-response bias, and increasing the internal validity of the study.

Furthermore, in order to accurately capture the exposure variable it would be useful to look at resident's exposure to the number of industrial wind turbines around them (e.g. number of industrial wind turbines within 2,000 meters) and the size, power, make and model of industrial wind turbines. One suggestion would be to create an industrial wind turbine exposure variable that could look something like this: (distance to closest industrial wind turbine×size/power of industrial wind turbine) + (number of industrial wind turbines within 2,000 meters×size/power of each industrial wind turbine within 2,000 meters). Using a calculation like this to determine an exposure variable would more accurately capture the picture of what people are living around versus assuming that all residents have exposure to only industrial wind turbine and that all industrial wind turbines are the same size.

Additionally, in order to accurately capture the outcome variables, and in relation to the potential sources of information bias mentioned above, it would be beneficial to measure objective health outcomes in future studies instead of subjective health outcomes. Using objective measures, such as sleep actigraphy or hair cortisol levels, to measure different health outcomes reduces the likelihood of information bias (e.g. people misunderstanding a survey question or unwilling to give the correct response) and will look at the health effects of industrial wind turbines from more of a physiological point of view.

Also, it is important for future studies that the exact locations of industrial wind turbines and residence locations be determined. In order to make this type of research stronger, a Global Positioning System (GPS) should be used to determine the exact coordinates of industrial wind turbine locations in Ontario as this will determine the accuracy of the industrial wind turbine locations used in this study. Similarly, a GPS should be used to determine the exact coordinates of survey respondent locations as this will determine the accuracy of the survey respondent locations used in this study. In this study, errors were not adjusted for but it would be useful to do this in future research (e.g. the standard deviation should be included in the models to improve accuracy).

Finally, in this study we saw that people are reporting living closer to industrial wind turbines than they actually live. Therefore, we have shown that self-reported distances should not be used in future research around renewable energy technologies but that calculated distances should be used instead. Also, given that the respondents in this study reported living closer to wind turbines than they actually do, it is important that setback distances be examined and re-assessed.

In conclusion, although this research suggests that there is a possible association between various health outcomes and how far someone lives from an industrial wind turbine, it is important to remember that there are several limitations to these conclusions, which weaken the internal validity of the study findings. These findings warrant further research including multiple studies with multiple designs on the subject of industrial wind turbines and health.

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APPENDIX A – MEDIA RELEASE

University of Waterloo renewable energy study coming to several communities

WATERLOO, Ont. (Monday, Jan. 28, 2013) – Over the next few weeks, some Ontario residents will receive surveys pertaining to the possible health effects of living near wind turbines. The questionnaires are part of the Quality of Life and Renewable Energy Technologies Study from the University of Waterloo.

The research team will send surveys to mailboxes of Bruce County, Dufferin County, Elgin County, Essex County, Frontenac County, Huron County, Norfolk County and Chatham-Kent residents who live within five kilometres of a wind turbine.

“These health studies are an important part of our Research Chair program by helping us understand the relationship between the renewable energy technologies and potential health effects," said Waterloo Professor Siva Sivoththman, the Ontario Research Chair in Renewable Energy Technologies and Health.

Professor Phil Bigelow, an epidemiologist at the School of Public Health and Health Systems at Waterloo, is spearheading the research examining the specific relationship between reported health effects and living near renewable energy technologies.

"It is critical that the survey captures the unique experiences of residents, so people who receive one in their mailboxes are highly encouraged to complete it," he said.

In appreciation of the time that it will take to fill out the survey, participants will be entered into a draw for a chance to win a $150 gift card for a store of the winner’s choice. Furthermore, selected participants will be invited to take part in the second part of the study, which will involve a more in-depth health assessment.

The University of Waterloo Renewal Energy Study will examine several different renewal energy sources. Approximately 5,000 residents living near these sources across Ontario will be invited to participate. For more information on the Ontario Research Chair program in Renewable Energy Technologies and Health, please visit http://www.orc-reth.uwaterloo.ca/.
For more information on the study, please contact Tanya Christidis at tchristi@uwaterloo.ca.

About the University of Waterloo
In just half a century, the University of Waterloo, located at the heart of Canada's technology hub, has become one of Canada's leading comprehensive universities with 35,000 full- and part-time students in undergraduate and graduate programs. Waterloo, as home to the world's largest post-secondary co-operative education program, embraces its connections to the world and encourages enterprising partnerships in learning, research

and discovery. In the next decade, the university is committed to building a better future for Canada and the world by championing innovation and collaboration to create solutions relevant to the needs of today and tomorrow. For more information about Waterloo, visit www.uwaterloo.ca.

About the Ontario Research Chair program in Renewable Energy Technologies and Health

The Ontario Research Chair program in Renewable Energy Technologies and Health (ORC-RETH) at the University of Waterloo is a multi-disciplinary research group promoting research and educational activities in renewable energy technologies (RETs) and their health and safety implications. Professor Siva Sivoththaman holds the Ontario Research Chair with annual funding of $300,000 for five years from the Ontario Ministry of Environment and administered by the Council of Ontario Universities (COU).

-30-

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APPENDIX B – INFORMATION LETTER

Quality of Life and Renewable Energy Technologies

Dear Resident,

The Ontario Research Chair program in Renewable Energy Technologies and Health (ORC-RETH) at the University of Waterloo is exploring if there is a relationship between quality of life and living within close proximity of renewable energy technologies such as solar farms, wind farms, and biogas plants. This study will use different methods like surveys and physical assessments in hopes of understanding the potential quality of life impacts that may result from renewable energy technologies in Ontario communities.

Your community has been selected by our research team as one of several communities to be included in this project. Your experience and perspective is very important to understanding the role renewable energy technologies play in quality of life across Ontario.

The enclosed survey is the first component of our research program. The survey should take approximately 30 minutes to complete. The questions are intended to provide general information about you, your health and personal well-being, your community, and renewable energy technologies. Questions about your health and demographic information are asked for study purposes only. **This survey is for adults who live in this house regularly. To ensure our study selects people at random, we are asking the adult (18 years or older) in your household with the next upcoming birthday to fill out this survey. Please fill out the survey by yourself and only complete responses based on your own experiences and not the experiences of others.**

You may change your mind about participation and not return the survey. All questions are voluntary and you do not have to complete all questions to participate. All information you provide will be considered confidential. To ensure the confidentiality of individuals' data, each participant will be identified by a participant identification code known only to the University of Waterloo researchers. Any publications or reports that result from this study will primarily report average responses of groups of participants. In the case where individual data may be presented, the individual will not be identified. Your information will be stored safely and securely at the University of Waterloo at the School of Public Health and Health Systems. Any identifying information will be retained for seven years, after which it will be destroyed by confidential shredding. While de-identified data will be retained indefinitely, after this point, no identifiers will exist linking you to the data collected during this study. All information you provide will be kept confidential, except as required under law. There are no known or anticipated risks to participation in this survey.

If you are interested in participating in this study, you can complete the survey on your own time and return the completed survey in the enclosed, self-addressed, stamped envelope. We will then enter your name into a draw. If selected, you will receive a $150 gift card for a store of your choice. The amount received is taxable. It is your responsibility to report the amount received for income tax purposes.

This study also involves a second component, which will include a more detailed health assessment in which you will be asked to undergo a heath assessment in your home by a nursing student and a research assistant from the RETH group. This assessment may include any of the following parts: providing a small hair sample, keeping a sleep diary and symptom journal for a week, collecting saliva samples for three days, completing a similar survey to this one, and allowing a research assistant to measure the Global Positioning System (GPS) coordinates of your home. If you are interested in being contacted to participate in the second component please indicate this on the contact form. Not all participants who volunteer to take part in this component will be selected. You will receive up to $75 if you are selected to participate, depending on which and how many parts of the assessment you participate in.

If you have any questions about this study please contact Tanya Christidis (Project Coordinator) at the University of Waterloo **1-519-888-4567 ext. 31342** or tchristi@uwaterloo.ca. For more information about the Ontario Research Chair program in Renewable Energy Technologies and Health please visit http://www.orc-reth.uwaterloo.ca/.

This study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. Should you have any comments or concerns resulting from your participation in this study, please contact Dr. Maureen Nummelin, Director of the Office of Research Ethics, at 1-519-888-4567, ext. 36005 or maureen.nummelin@uwaterloo.ca. Thank you in advance for your interest in this project.

Yours sincerely,

University of Waterloo Renewable Energy Technologies and Health Research Group

Phil Bigelow (PhD), Steve McColl (PhD), Laurie Hoffman-Goetz (PhD), Jane Law (PhD), Shannon Majowicz (PhD), Siva Sivoththaman (PhD), Mahtab Kamali (PhD), Veronique Boscart (RN, PhD), Leila Jalali (MD), Susan Yates (MSc, RN), Tanya Christidis (MSc), James Lane (MSc Candidate), Samriti Mishra (MSC Candidate), Claire Paller (MSc Candidate)

APPENDIX C – CONTACT INFORMATION FORM

Contact Information Form – Survey Participant

This survey is for adults who live in this house regularly. To ensure our study selects people at random, we are asking the adult (18 years or older) in your household with the next upcoming birthday to fill out this survey.

Please provide your name, address, phone number, and email address below. This information will only be used to contact you if your name has been selected in our draw, provide you feedback on the study, and to contact you if you choose to be considered for participation in component two of the study. Include this contact information form in the return envelope, along with your completed survey.

Name:	
Mailing Address:	
Phone Number:	
Email Address (optional):	
Signature:	**Date:**

The next portion of our research project will be a more thorough assessment of health. Participants who took part in this survey will be considered for the second assessment only if they are interested in doing so. Participants in component two will undergo a health assessment in their home by a nursing student and a research assistant from the Renewable Energy Technologies and Health group, provide a small hair sample, keep a sleep diary and symptom journal for a week, collect saliva samples for three days, complete a similar survey to this one, and allow researchers to measure the global positioning system (GPS) coordinates of their home. Preference will be given to interested participants who live closest to renewable energy technologies.

If selected, are you interested in being contacted for participation in the second part of this study? ☐ Yes ☐ No

APPENDIX D – REMINDER POSTCARD

February 15, 2013

Recently a survey was delivered to you as part of the University of Waterloo's study looking at quality of life for people living near renewable energy technologies such as wind turbines and solar panels.

If the person with the next upcoming birthday in your household has already completed and returned the survey, please accept our sincere thanks. If the survey has not yet been completed, please have the person in your household that is 18 years or older with the next upcoming birthday complete and return the survey as soon as possible. We are especially grateful for your help with this important study.

If you did not receive a survey, or if it was misplaced, please call the Project Coordinator, Tanya Christidis, at 519-888-4567 ext. 31342 or email her at tchristi@uwaterloo.ca and she will send you another survey.

Sincerely,

The Renewable Energy Technologies and Health research team

APPENDIX E – DISTRIBUTION OF VERTIGO AND TINNITUS SCORES

Variable	**1 (never or seldom)**	**2 (about once a month)**	**3 (about once a week)**	**4 (almost daily)**
Vertigo	296	47	20	19
TOTAL %	**77.49**	**22.51**		
Tinnitus	246	42	25	70
TOTAL %	**64.23**	**35.77**		

APPENDIX F – SATISFACTION WITH LIFE SCALE QUESTIONS

Below are five statements with which you may agree or disagree. Using the boxes below, indicate your agreement with each item. Please be open and honest in your responses.

	Strongly disagree			Nether agree nor disagree			Strongly Agree
42. In most ways my life is close to my ideal.	1	2	3	4	5	6	7
43. The conditions of my life are excellent.	1	2	3	4	5	6	7
44. I am satisfied with my life.	1	2	3	4	5	6	7
45. So far I have gotten the important things I want in life.	1	2	3	4	5	6	7
46. If I could live my life over, I would change almost nothing.	1	2	3	4	5	6	7

APPENDIX G – SF-12v2 HEALTH SURVEY QUESTIONS

The following questions ask general information about your health and well-being.

	Excell ent	Very Good	Good	Fair	Poor
1. In general, would you say your health is...	1	2	3	4	5

The following questions are about activities you might do during a typical day. Does **<u>your health now limit you</u>** in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
22. <u>Moderate activities</u>, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	☐	☐	☐
23. Climbing <u>several</u> flights of stairs	☐	☐	☐

During the **<u>past 4 weeks</u>** how much of the time have you had any of the following problems with your work or other regular daily activities **<u>as a result of your physical health</u>**?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
24. <u>Accomplished less</u> than you would like	1	2	3	4	5
25. Were limited in the <u>kind</u> of work or other activities	1	2	3	4	5

During the **<u>past 4 weeks</u>** how much of the time have you had any of the following problems with your work or other regular daily activities **<u>as a result of any emotional problems</u>** (such as feeling depressed or anxious)?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
24. <u>Accomplished less</u> than you would like	1	2	3	4	5
25. Did work or other activities <u>less carefully than usual</u>	1	2	3	4	5

28. During the **past 4 weeks**, how much did pain interfere with your normal work (including both work outside the home and housework)?

☐ Not at all ☐ A little bit ☐ Moderately ☐ Quite a bit ☐ Extremely

These questions are about how you feel and how things have been with you **during the past 4 weeks**. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the **past 4 weeks…**

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
29. Have you felt calm and peaceful?	1	2	3	4	5
30. Did you have a lot of energy?	1	2	3	4	5
31. Have you felt downhearted and depressed?	1	2	3	4	5

41. During the **past 4 weeks**, how much of the time has your **physical health or emotional problems** interfered with your social activities (like visiting with friends, relatives, etc.)?

☐ All of the time ☐ Most of the time ☐ Some of the time ☐ A little of the time ☐ None of the time

APPENDIX H – QUESTIONS ADAPTED FROM PROJECT WINDFARM$_{\text{PERCEPTION}}$ STUDY

How often have you been troubled by the following symptoms in the last month?

	Never or seldom	About once a month	About once a week	Almost Daily
4. Headache	1	2	3	4
5. Depression	1	2	3	4
6. Not very sociable, wanting to be alone	1	2	3	4
7. Irritable	1	2	3	4
8. Resigned (e.g. feel like you've given up)	1	2	3	4
9. Fearful	1	2	3	4
10. Concentration problems	1	2	3	4
11. Nausea (e.g. upset or uneasy stomach)	1	2	3	4
12. Vertigo (e.g. feel as if the room is spinning)	1	2	3	4
13. Mood changes	1	2	3	4
14. Migraine Headache	1	2	3	4
15. Undue tiredness	1	2	3	4
16. Pain and stiffness in the back, neck or shoulders	1	2	3	4
17. Feeling tense or stressed	1	2	3	4
18. Unusual body sensations	1	2	3	4

How often have you been troubled by the following symptoms in the last month?

	Never or seldom	About once a month	About once a week	Almost Daily
19. Tinnitus (ringing in the ears)	1	2	3	4
20. Other (please specify):	1	2	3	4

____

APPENDIX I – PITTSBURGH SLEEP QUALITY INDEX QUESTIONS

The following section asks general information about your sleep habits.

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month.

During the past month…

1. What time have you usually gone to bed? *(please also circle a.m. or p.m.)*	___________ a.m./p.m.
2. How long has it taken you to fall asleep each night? (Once you have decided to go to sleep)	___________ minutes
3. What time have you usually woken up in the morning? *(please also circle a.m. or p.m.)*	___________ a.m./p.m.
4. How many hours of actual sleep do you get at night? (This may be different than the number of hours you spend in bed)	___________ hours _________ minutes

5. During the past month, how would you rate your sleep quality overall?

☐ Very Good ☐ Fairly Good ☐ Fairly Bad ☐ Very Bad

During the past month, how often have you had trouble sleeping because you…

	Not in the past month	Less than once a week	1-2 times a week	3+ times a week
6. Cannot get to sleep within 30 minutes?	1	2	3	4
7. Wake up in the middle of the night or early morning?	1	2	3	4
8. Have to get up to use the bathroom?	1	2	3	4
9. Cannot breathe comfortably?	1	2	3	4

During the past month, how often have you had trouble sleeping because you…

	Not in the past month	Less than once a week	1-2 times a week	3+ times a week
10. Cough or snore loudly?	1	2	3	4
11. Feel too cold?	1	2	3	4
12. Feel too hot?	1	2	3	4
13. Have bad dreams?	1	2	3	4
14. Have pain?	1	2	3	4
15. Other (please specify):	1	2	3	4

→ ____

During the past month…

	Not in the past month	Less than once a week	1-2 times a week	3+ times a week
16. How often have you taken medicine (prescribed or "over the counter") to help you sleep?	1	2	3	4
17. How often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	1	2	3	4
18. How much of a problem has it been for you to keep up enthusiasm to get things done?	1	2	3	4

APPENDIX J – REGRESSION MODELS USED FOR ANALYSIS

Variable	GENMOD Model
PSQI	psqi=ln_dist age gender county / dist=normal link=ID
PSQI_bin	psqi_bin=ln_dist age gender county / dist=binomial link = logit
PCS	PCS=ln_dist county gender age / dist=normal link=ID
PCS_bin	PCS_bin= ln_dist age gender county / dist=binomial link = logit
MCS	MCS=ln_dist county gender age / dist=normal link=ID
Depression_bin	depression_bin= ln_dist age gender county/ dist=binomial link = logit
SWLS	SWLS=ln_dist age gender county / dist=normal link=ID
SWLS_bin	SWLS_bin= ln_dist age gender county/ dist=binomial link = logit
WTS_index	WTS_index=ln_dist age gender county /dist=normal link=ID
WTS_bin	WTS_bin= ln_dist age gender county/ dist=binomial link = logit
Headache	headache= ln_dist age gender county / dist=poisson link = log
Irritable	irritable= ln_dist age gender county / dist=poisson link = log
Concentration Problems	concentration= ln_dist age gender county / dist=poisson link = log
Nausea	nausea= ln_dist age gender county / dist=poisson link = log
Vertigo_bin	vertigo_bin= ln_dist age gender county/ dist=binomial link = logit
Undue Tiredness	tiredness= ln_dist age gender county / dist=poisson link = log
Tinnitus_bin	tinnitus_bin= ln_dist age gender county / dist=b link = logit
Overall Sleep Quality	sleep_quality= ln_dist age gender county / dist=normal link=ID

APPENDIX K – RESPONSE RATES BY COUNTY

County	**Wind Farm**	**Total Survey Sent**	**Total Survey Responses**	**Response Rate**
Bruce	Enbridge	828	57	6.88%
Chatham-Kent	Raleigh	415	39	9.40%
Dufferin	Melancthon	944	84	8.90%
Elgin	Erie Shores	726	55	7.58%
Essex	Comber	1222	97	7.94%
Frontenac	Wolfe Island	155	13	8.39%
Huron	Kingsbridge	473	37	7.82%
Norfolk	Frogmore/Cultus/Clear Creek	113	14	12.39%
		No address provided	16	-
TOTAL		**4876**	**412**	**8.45%**

APPENDIX L – CORRELATION MATRIX FOR ALL VARIABLES USED IN ANALYSIS

The CORR Procedure

24 Variables:	age gender IWT_number residence_yrs PSQI psqi_bin PCS PCS_bin MCS Depression_bin SWLS SWLS_bin WTS_Index WTS_bin Headache Irritable Concentration Nausea Vertigo vertigo_bin Tiredness Tinnitus tinnitus_bin Sleep_Quality

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	age	gender	IWT_number	residence_yrs	PSQI	psqi_bin	PCS	PCS_bin	MCS	Depression_bin	SWLS	SWLS_bin	WTS_Index	WTS_bin	Headache	Irritable	Concentration	Nausea	Vertigo	vertigo_bin	Tiredness	Tinnitus	tinnitus_bin	Sleep_Quality
	1.00000	-0.15727	-0.13577	0.51939	-0.03113	-0.09610	-0.34377	0.30807	0.23080	-0.08875	-0.01447	0.03601	-0.21429	-0.14660	-0.28913	-0.26170	-0.13442	-0.15476	-0.03624	-0.03473	-0.03068	0.03972	0.00962	0.09140
		0.0019	0.0075	<.0001	0.5628	0.0589	<.0001	<.0001	<.0001	0.0812	0.7774	0.4800	<.0001	0.0038	<.0001	<.0001	0.0090	0.0025	0.4818	0.5002	0.5521	0.4401	0.8517	0.0783
age	387	386	387	379	348	387	383	387	383	387	384	387	385	387	378	380	377	379	379	379	378	380	380	372
	-0.15727	1.00000	-0.04945	-0.09186	0.09324	0.03962	0.02523	0.04353	-0.04486	0.00541	0.01847	-0.01657	0.01972	0.09552	0.18439	-0.00923	0.02977	0.05485	0.04836	0.04614	0.04990	-0.15568	-0.14647	0.04270
	0.0019		0.3294	0.0726	0.0815	0.4347	0.6207	0.3907	0.3788	0.9150	0.7169	0.7440	0.6983	0.0592	0.0003	0.8569	0.5624	0.2843	0.3452	0.3679	0.3307	0.0022	0.0040	0.4090
gender	386	391	391	383	350	391	387	391	387	391	388	391	389	391	382	384	381	383	383	383	382	384	384	376
	-0.13577	-0.04945	1.00000	0.01835	0.10424	0.06707	-0.01772	0.03737	-0.09506	0.10198	0.01502	-0.02928	0.07962	0.07665	0.03496	0.03645	0.02277	0.06918	0.16509	0.17631	0.05583	0.00696	0.04061	-0.02703
	0.0075	0.3294		0.7192	0.0507	0.1829	0.7269	0.4584	0.0604	0.0425	0.7671	0.5613	0.1151	0.1278	0.4934	0.4741	0.6561	0.1744	0.0011	0.0005	0.2739	0.8913	0.4250	0.5998
IWT_number	387	391	396	386	352	396	391	396	391	396	391	396	393	396	386	388	385	387	387	387	386	388	388	379
	0.51939	-0.09186	0.01835	1.00000	-0.04001	-0.04386	-0.23821	0.18014	0.19517	-0.06660	0.06844	-0.04237	-0.13443	-0.12243	-0.08773	-0.18346	-0.12077	-0.13377	0.05096	0.05493	-0.04428	-0.02091	-0.03695	0.03585
	<.0001	0.0726	0.7192		0.4588	0.3901	<.0001	0.0004	0.0001	0.1916	0.1814	0.4065	0.0083	0.0161	0.0889	0.0003	0.0191	0.0092	0.3231	0.2868	0.3913	0.6849	0.4732	0.4912
residence_yrs	379	383	386	386	345	386	382	386	382	386	383	386	384	386	377	379	376	378	378	378	377	379	379	371
	-0.03113	0.09324	0.10424	-0.04001	1.00000	0.77063	-0.17182	0.14714	-0.32803	0.20143	-0.16557	0.17430	0.38997	0.39571	0.29098	0.24572	0.29663	0.28464	0.22094	0.20429	0.45578	0.11060	0.11112	-0.23115
	0.5628	0.0815	0.0507	0.4588		<.0001	0.0012	0.0057	<.0001	0.0001	0.0019	0.0010	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0001	<.0001	0.0392	0.0383	<.0001
PSQI	348	350	352	345	352	352	352	352	352	352	351	352	352	352	346	348	346	349	348	348	347	348	348	352
	-0.09610	0.03962	0.06707	-0.04386	0.77063	1.00000	-0.05483	0.01415	-0.14288	0.03105	-0.07505	0.02984	0.22634	0.20538	0.18342	0.11750	0.12871	0.17157	0.15439	0.14711	0.25783	0.03399	0.04467	-0.06924
	0.0589	0.4347	0.1829	0.3901	<.0001		0.2794	0.7789	0.0046	0.5378	0.1385	0.5538	<.0001	<.0001	0.0003	0.0206	0.0115	0.0007	0.0023	0.0037	<.0001	0.5044	0.3802	0.1786
psqi_bin	387	391	396	386	352	396	391	396	391	396	391	396	393	396	386	388	385	387	387	387	386	388	388	379
	-0.34377	0.02523	-0.01772	-0.23821	-0.17182	-0.05483	1.00000	-0.85806	-0.10087	-0.10493	0.28914	-0.23479	-0.27444	-0.21271	-0.10023	-0.06938	-0.14130	-0.17735	-0.23419	-0.21306	-0.32311	-0.18319	-0.16120	0.29369
	<.0001	0.6207	0.7269	<.0001	0.0012	0.2794		<.0001	0.0462	0.0381	<.0001	<.0001	<.0001	<.0001	0.0497	0.1737	0.0055	0.0005	<.0001	<.0001	<.0001	0.0003	0.0015	<.0001
PCS	383	387	391	382	352	391	391	391	391	391	389	391	391	391	384	386	384	386	386	386	385	387	387	378
	0.30807	0.04353	0.03737	0.18014	0.14714	0.01415	-0.85806	1.00000	0.05128	0.12966	-0.23665	0.19656	0.21898	0.15686	0.08260	0.09030	0.11633	0.13558	0.17086	0.15277	0.28993	0.12886	0.10647	-0.23899
	<.0001	0.3907	0.4584	0.0004	0.0057	0.7789	<.0001		0.3119	0.0098	<.0001	<.0001	<.0001	0.0017	0.1051	0.0756	0.0224	0.0076	0.0007	0.0026	<.0001	0.0111	0.0360	<.0001
PCS_bin	387	391	396	386	352	396	391	396	391	396	391	396	393	396	386	388	385	387	387	387	386	388	388	379
	0.23080	-0.04486	-0.09506	0.19517	-0.32803	-0.14288	-0.10087	0.05128	1.00000	-0.62429	0.31998	-0.29277	-0.55667	-0.50077	-0.28815	-0.52182	-0.52764	-0.31457	-0.24170	-0.22900	-0.51531	-0.17648	-0.17897	0.33240
	<.0001	0.3788	0.0604	0.0001	<.0001	0.0046	0.0462	0.3119		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0005	0.0004	<.0001
MCS	383	387	391	382	352	391	391	391	391	391	389	391	391	391	384	386	384	386	386	386	385	387	387	378
	-0.08875	0.00541	0.10198	-0.06660	0.20143	0.03105	-0.10493	0.12966	-0.62429	1.00000	-0.28353	0.33409	0.40050	0.37390	0.25811	0.35162	0.39033	0.33406	0.22836	0.20872	0.36320	0.13658	0.13507	-0.29862
	0.0812	0.9150	0.0425	0.1916	0.0001	0.5378	0.0381	0.0098	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0071	0.0077	<.0001
Depression_bin	387	391	396	386	352	396	391	396	391	396	391	396	393	396	386	388	385	387	387	387	386	388	388	379
	-0.01447	0.01847	0.01502	0.06844	-0.16557	-0.07505	0.28914	-0.23665	0.31998	-0.28353	1.00000	-0.78814	-0.27463	-0.24085	-0.15057	-0.21565	-0.21397	-0.15257	-0.12261	-0.11739	-0.26899	-0.11434	-0.12495	0.30500
	0.7774	0.7169	0.7671	0.1814	0.0019	0.1385	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	0.0031	<.0001	<.0001	0.0027	0.0161	0.0212	<.0001	0.0247	0.0140	<.0001
SWLS	384	388	391	383	351	391	389	391	389	391	391	391	391	391	384	386	383	385	385	385	384	386	386	377
	0.03601	-0.01657	-0.02928	-0.04237	0.17430	0.02984	-0.23479	0.19656	-0.29277	0.33409	-0.78814	1.00000	0.21750	0.20745	0.14877	0.14782	0.17871	0.14478	0.11623	0.11704	0.20329	0.05189	0.04909	-0.27354
	0.4800	0.7440	0.5613	0.4065	0.0010	0.5538	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	0.0034	0.0035	0.0004	0.0043	0.0222	0.0213	<.0001	0.3079	0.3349	<.0001
SWLS_bin	387	391	396	386	352	396	391	396	391	396	391	396	393	396	386	388	385	387	387	387	386	388	388	379
	-0.21429	0.01972	0.07962	-0.13443	0.38997	0.22634	-0.27444	0.21898	-0.55667	0.40050	-0.27463	0.21750	1.00000	0.79246	0.57273	0.61949	0.67345	0.52541	0.49259	0.47336	0.74169	0.50748	0.48893	-0.58132
	<.0001	0.6983	0.1151	0.0083	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
WTS_Index	385	389	393	384	352	393	391	393	391	393	391	393	393	393	386	388	385	387	387	387	386	388	388	379

The CORR Procedure

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	age	gender	IWT_number	residence_yrs	PSQI	psqi_bin	PCS	PCS_bin	MCS	Depression_bin	SWLS	SWLS_bin
WTS_bin	-0.14660	0.09552	0.07665	-0.12243	0.39571	0.20538	-0.21271	0.15686	-0.50077	0.37390	-0.24085	0.20745
	0.0038	0.0592	0.1278	0.0161	<.0001	<.0001	<.0001	0.0017	<.0001	<.0001	<.0001	<.0001
	387	391	396	386	352	396	391	396	391	396	391	396
Headache	-0.28913	0.18439	0.03496	-0.08773	0.29098	0.18342	-0.10023	0.08260	-0.28815	0.25811	-0.15057	0.14877
	<.0001	0.0003	0.4934	0.0889	<.0001	0.0003	0.0497	0.1051	<.0001	<.0001	0.0031	0.0034
	378	382	386	377	346	386	384	386	384	386	384	386
Irritable	-0.26170	-0.00923	0.03645	-0.18346	0.24572	0.11750	-0.06938	0.09030	-0.52182	0.35162	-0.21565	0.14782
	<.0001	0.8569	0.4741	0.0003	<.0001	0.0206	0.1737	0.0756	<.0001	<.0001	<.0001	0.0035
	380	384	388	379	348	388	386	388	386	388	386	388
Concentration	-0.13442	0.02977	0.02277	-0.12077	0.29663	0.12871	-0.14130	0.11633	-0.52764	0.39033	-0.21397	0.17871
	0.0090	0.5624	0.6561	0.0191	<.0001	0.0115	0.0055	0.0224	<.0001	<.0001	<.0001	0.0004
	377	381	385	376	346	385	384	385	384	385	383	385
Nausea	-0.15476	0.05485	0.06918	-0.13377	0.28464	0.17157	-0.17735	0.13558	-0.31457	0.33406	-0.15257	0.14478
	0.0025	0.2843	0.1744	0.0092	<.0001	0.0007	0.0005	0.0076	<.0001	<.0001	0.0027	0.0043
	379	383	387	378	349	387	386	387	386	387	385	387
Vertigo	-0.03624	0.04836	0.16509	0.05096	0.22094	0.15439	-0.23419	0.17086	-0.24170	0.22836	-0.12261	0.11623
	0.4818	0.3452	0.0011	0.3231	<.0001	0.0023	<.0001	0.0007	<.0001	<.0001	0.0161	0.0222
	379	383	387	378	348	387	386	387	386	387	385	387
vertigo_bin	-0.03473	0.04614	0.17631	0.05493	0.20429	0.14711	-0.21306	0.15277	-0.22900	0.20872	-0.11739	0.11704
	0.5002	0.3679	0.0005	0.2868	0.0001	0.0037	<.0001	0.0026	<.0001	<.0001	0.0212	0.0213
	379	383	387	378	348	387	386	387	386	387	385	387
Tiredness	-0.03068	0.04990	0.05583	-0.04428	0.45578	0.25783	-0.32311	0.28993	-0.51531	0.36320	-0.26899	0.20329
	0.5521	0.3307	0.2739	0.3913	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	378	382	386	377	347	386	385	386	385	386	384	386
Tinnitus	0.03972	-0.15568	0.00696	-0.02091	0.11060	0.03399	-0.18319	0.12886	-0.17648	0.13658	-0.11434	0.05189
	0.4401	0.0022	0.8913	0.6849	0.0392	0.5044	0.0003	0.0111	0.0005	0.0071	0.0247	0.3079
	380	384	388	379	348	388	387	388	387	388	386	388
tinnitus_bin	0.00962	-0.14647	0.04061	-0.03695	0.11112	0.04467	-0.16120	0.10647	-0.17897	0.13507	-0.12495	0.04909
	0.8517	0.0040	0.4250	0.4732	0.0383	0.3802	0.0015	0.0360	0.0004	0.0077	0.0140	0.3349
	380	384	388	379	348	388	387	388	387	388	386	388
Sleep_Quality	0.09140	0.04270	-0.02703	0.03585	-0.23115	-0.06924	0.29369	-0.23899	0.33240	-0.29862	0.30500	-0.27354
	0.0783	0.4090	0.5998	0.4912	<.0001	0.1786	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	372	376	379	371	352	379	378	379	378	379	377	379

	WTS_Index	WTS_bin	Headache	Irritable	Concentration	Nausea	Vertigo	vertigo_bin	Tiredness	Tinnitus	tinnitus_bin	Sleep_Quality
WTS_bin	0.79246	1.00000	0.48377	0.46592	0.60662	0.50114	0.44053	0.41778	0.66166	0.40037	0.38092	-0.48051
	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	393	396	386	388	385	387	387	387	386	388	388	379
Headache	0.57273	0.48377	1.00000	0.25789	0.26760	0.36591	0.29034	0.28259	0.37278	0.13420	0.12768	-0.26999
	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0085	0.0123	<.0001
	386	386	386	385	380	382	383	383	381	384	384	372
Irritable	0.61949	0.46592	0.25789	1.00000	0.43706	0.21921	0.14910	0.14215	0.42473	0.19379	0.19211	-0.33309
	<.0001	<.0001	<.0001		<.0001	<.0001	0.0034	0.0052	<.0001	0.0001	0.0001	<.0001
	388	388	385	388	383	385	385	385	384	386	386	374
Concentration	0.67345	0.60662	0.26760	0.43706	1.00000	0.35336	0.31151	0.29140	0.48916	0.23642	0.21949	-0.29895
	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	385	385	380	383	385	384	384	384	383	384	384	371
Nausea	0.52541	0.50114	0.36591	0.21921	0.35336	1.00000	0.36756	0.35058	0.35691	0.16691	0.17109	-0.28446
	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	0.0010	0.0007	<.0001
	387	387	382	385	384	387	386	386	385	386	386	373
Vertigo	0.49259	0.44053	0.29034	0.14910	0.31151	0.36756	1.00000	0.99132	0.34744	0.25179	0.24145	-0.27842
	<.0001	<.0001	<.0001	0.0034	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001
	387	387	383	385	384	386	387	387	385	387	387	373
vertigo_bin	0.47336	0.41778	0.28259	0.14215	0.29140	0.35058	0.99132	1.00000	0.33191	0.22673	0.21938	-0.26377
	<.0001	<.0001	<.0001	0.0052	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
	387	387	383	385	384	386	387	387	385	387	387	373
Tiredness	0.74169	0.66166	0.37278	0.42473	0.48916	0.35691	0.34744	0.33191	1.00000	0.25066	0.24968	-0.42666
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
	386	386	381	384	383	385	385	385	386	385	385	372
Tinnitus	0.50748	0.40037	0.13420	0.19379	0.23642	0.16691	0.25179	0.22673	0.25066	1.00000	0.97335	-0.23571
	<.0001	<.0001	0.0085	0.0001	<.0001	0.0010	<.0001	<.0001	<.0001		<.0001	<.0001
	388	388	384	386	384	386	387	387	385	388	388	374
tinnitus_bin	0.48893	0.38092	0.12768	0.19211	0.21949	0.17109	0.24145	0.21938	0.24968	0.97335	1.00000	-0.22938
	<.0001	<.0001	0.0123	0.0001	<.0001	0.0007	<.0001	<.0001	<.0001	<.0001		<.0001
	388	388	384	386	384	386	387	387	385	388	388	374
Sleep_Quality	-0.58132	-0.48051	-0.26999	-0.33309	-0.29895	-0.28446	-0.27842	-0.26377	-0.42666	-0.23571	-0.22938	1.00000
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	
	379	379	372	374	371	373	373	373	372	374	374	379

APPENDIX M – COUNTY LEVEL COMPARISON OF SAMPLE POPULATION TO COMPARISON POPULATION

County	Demographic	Sample Population	Comparison	P-Value
Bruce				
	# Survey Respondents (# Surveys Sent Out)	57 (828)	66,102[1]	--
	Median Age	57.00	47.00[1]	--
	Sex- Male	63.13%	49.55%[1]	0.04036
	Married	66.66%	64.26%[1]	0.70394
	Median Income[ab]	60,000	65,379[2]	--
	Post-Secondary Education	61.40%	35.01%[2]	<0.005
Chatham-Kent				
	# Survey Respondents (# Surveys Sent Out)	39 (415)	104,075[3]	--
	Median Age	64.00	43.80[3]	--
	Sex- Male	46.15%	48.63%[3]	0.75656
	Married	73.68%	59.56%[3]	0.07186
	Median Income	60,000	63,218[4]	--
	Post-Secondary Education	43.59%	31.41%[4]	0.101
Dufferin				
	# Survey Respondents (# Surveys Sent Out)	84 (944)	56,881[5]	--
	Median Age	55.00	40.00[5]	--
	Sex- Male	45.78%	49.42%[5]	0.50286
	Married	83.13%	61.28%[5]	<0.005
	Median Income	90,000	75,143[6]	--
	Post-Secondary Education	62.65%	34.71%[6]	<0.005
Elgin				
	# Survey Respondents (# Surveys Sent Out)	(55) 726	87,461[7]	--
	Median Age	57.00	40.90[7]	--
	Sex- Male	44.44%	49.18%[7]	0.48392
	Married	86.19%	62.45%[7]	0.00028
	Median Income	60,000	66,410[8]	--
	Post-Secondary Education	43.64%	31.55%[8]	0.0536
Essex				
	# Survey Respondents (# Surveys Sent Out)	97 (1222)	388,782[9]	--

	Median Age	57.00	40.80[9]	--
	Sex- Male	58.51%	49.19%[9]	0.06576
	Married	85.26%	57.14%[9]	<0.005
	Median Income	90,000	71,605[10]	--
	Post-Secondary Education	72.63%	37.46%[10]	<0.005
Frontenac				
	# Survey Respondents (# Surveys Sent Out)	13 (155)	149,738[11]	--
	Median Age	61.00	41.60[11]	--
	Sex- Male	69.23%	48.86%[11]	0.14156
	Married	83.33%	56.23%[11]	0.04884
	Median Income	60,000	67,913[12]	--
	Post-Secondary Education	76.92%	46.10%[12]	0.02574
Huron				
	# Survey Respondents (# Surveys Sent Out)	37 (473)	59,100[13]	--
	Median Age	58.00	45.10[13]	--
	Sex- Male	43.24%	49.28%[13]	0.4654
	Married	67.56%	63.98%[13]	0.65272
	Median Income	60,000	62,446[14]	--
	Post-Secondary Education	44.44%	30.25%[14]	0.0601
Haldimand - Norfolk				
	# Survey Respondents (# Surveys Sent Out)	14 (113)	109,118[15]	--
	Median Age	46.00	44.80[15]	--
	Sex- Male	57.14%	49.81%[15]	0.58232
	Married	85.71%	62.97%[15]	0.0784
	Median Income	30,000	64,776[16]	--
	Post-Secondary Education	30.94%	50.00%[16]	0.15272

[a]Total income for sample population was calculated by using the mid-point of a range. The total income is the sum of the total incomes received by all household members from all sources, before taxes, in the past 12 months. [b]The total income for the comparison population is the sum of the total incomes of all members of that family. Total income refers to the total money income received from various sources during calendar year 2005 by persons 15 years of age and over

[1]Data from Statistics Canada, 2012a. [2]Data from Statistics Canada, 2007a. [3]Data from Statistics Canada, 2012b. [4]Data from Statistics Canada, 2007b. [5]Data from Statistics Canada, 2012c. [6]Data from Statistics Canada, 2007c. [7]Data from Statistics Canada, 2012d. [8]Data from Statistics Canada, 2007d. [9]Data from Statistics Canada, 2012e. [10]Data from Statistics Canada, 2007e. [11]Data from Statistics Canada, 2012f. [12]Data from Statistics Canada, 2007f. [13]Data from Statistics Canada, 2012g. [14]Data from Statistics Canada, 2007g. [15]Data from Statistics Canada, 2012h. [16]Data from Statistics Canada, 2007h.