International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns

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Introduction

The generation of electrical energy from wind, or wind energy, is a priority for the United States and the state of Minnesota. At the national level, the United States Department of Energy has published a report called 20% Wind Energy by 2030, created tax credit breaks for developing and using renewable energy, and funded wind energy research and development.[1] However, there is no federal renewable portfolio standard requiring that increased amounts of the United States' energy come from renewable energy sources, although thirty of the fifty states have such a standard.[2] Minnesota's renewable energy objective calls for 25% of the state's electrical energy to come from renewable sources including wind energy by 2025.[3]

While many people support wind energy, some have become concerned about possible impacts to their quality of life due to wind turbines, including noise, shadow flicker, and visual impacts, especially when they believe a wind turbine may be placed too close to their home. There is no worldwide agreement on appropriate wind turbine setback distances from homes; in fact, there is very limited awareness of wind turbine setbacks in other countries, or why a particular setback distance or limit was chosen. This report attempts to identify and clarify existing governmental requirements and recommendations regarding wind turbine setbacks from residences. It also attempts to identify the rationale behind current policies and whether or not the policies are based on public opinion or research. This report does not argue in favor of or against wind power, nor does it identify a best setback distance or measure. The goal of this report is to provide a resource of existing policies and recommendations regarding setbacks from residences in major wind energy-producing countries besides the United States.

Method

For this report, a variety of professionals working on renewable energy issues within national and regional governments, wind energy associations, wind energy development companies, and other areas were contacted by email. The email requested information regarding wind energy policies and recommendations about wind turbine setbacks, noise, shadow flicker, and other possible concerns. A transcript of a basic email is included in Appendix A. A list of persons who responded, and their positions, is included in Appendix B. The information gathered from these responses was supplemented by extensive examination of government websites, documents, guidelines, and policies. Google translate was used to translate documents, policies,

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[1] U.S. Department of Energy. (2008). 20% wind energy by 2030. Retrieved from http://www1.eere.energy.gov/windandhydro/wind_2030.html

[2] North Carolina Solar Center, & the Interstate Renewable Energy Council (IREC). (2011). DSIRE: Database of state incentives for renewables and efficiency: Federal incentives/policies for renewables and efficiency: Financial incentives. Retrieved from http://www.dsireusa.org/incentives/index.cfm?state=us

[3] State of Minnesota Office of Revisor of Statutes. Minnesota statues 2007: Chapter 216B.1691: Public Utilities: Renewable energy objectives. Retrieved from https://www.revisor.mn.gov/bin/getpub.php?pubtype=stat_chap&year=current&chapter=216b#stat.216B.1691.0

and websites not available in English. As translation services are not entirely accurate, misinterpretations may have resulted in inaccuracies. However, as a large percentage of this information came from experts on their countries' wind energy policies, and care was taken in reading translated documents, this document is believed to be accurate.

Countries were chosen based on their existing onshore wind energy capacity in 2010. The top 15 wind energy producers in 2010 were China, USA, Germany, Spain, India, Italy, France, United Kingdom, Canada, Denmark, Portugal, Japan, the Netherlands, Sweden, Australia, and Ireland. The wind energy capacities of these countries are shown in Figure 1. Because of language translation difficulties, China, India, and Japan were not included in this report. Additionally, U.S. federal and state wind siting policies were not included as the aim of this report was to examine and summarize recommendations and policies in major wind energy producing countries outside the U. S.* The other top 15 countries are included in this report, along with the European Union and New Zealand due to references to their policies in other documents. New Zealand's wind energy capacity is also included in Figure 1.

In this document, a setback or setback distance refers to the distance between a wind turbine and a residence or residential area. A noise limit refers to the maximum acceptable level of noise at a residence. Shadow flicker refers to the effect when the sun is behind rotating turbine blades and produces an intermittent shadow. In this document, a requirement or guideline for setback distances refers specifically to policies or recommendations regarding distances in terms of a unit of length or a multiplication of a turbine section (i.e. four times the height), not noise or shadow flicker requirements or guidelines. It is acknowledged that noise limits and shadow flicker policies are used to determine wind turbine setback distances, but because there are many countries that have a setback distance, a noise limit, and a shadow flicker limit these terms will be kept separate. Additionally, many wind energy professionals responded that their country did not have wind turbine setbacks but had noise limits or standards, so these terms are kept separate in this report. Wind energy terms and noise terms are listed in Appendices C and D, respectively. The policies and recommendations included in this report generally do not apply to small wind energy turbines that produce less than 100 kilowatts of energy.

*Policies in the USA are not covered in this report as they will be published separately in the fall of 2011 by the NARUC.

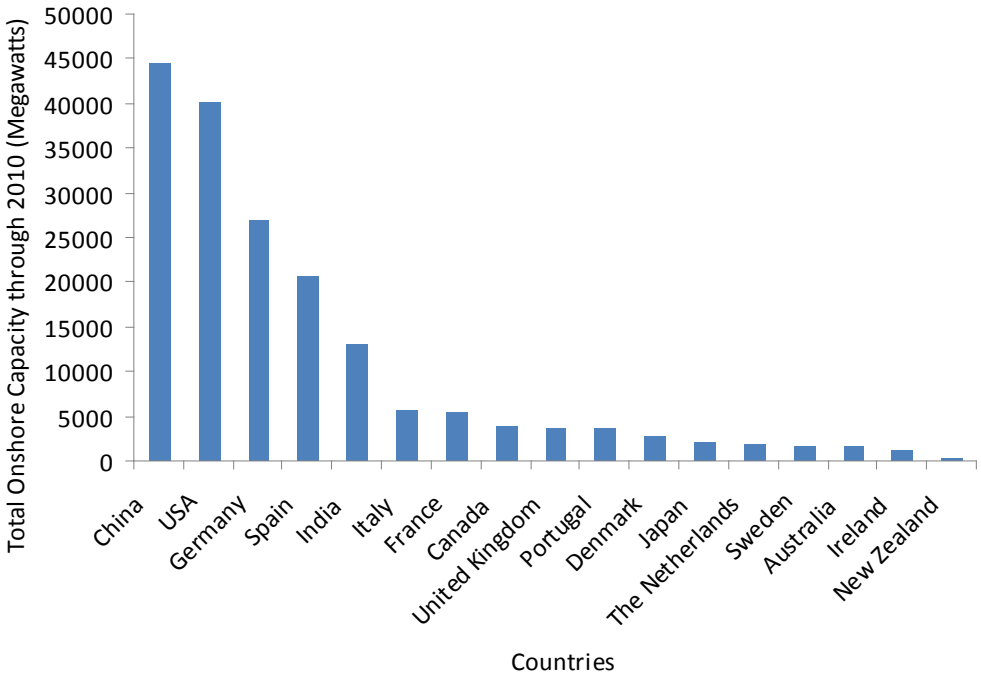

Figure 1: Total Onshore Wind Energy Capacity through 2010.[4]

Results

European Union

The European Union has a strong focus on reducing environmental factors leading to climate change and has thus published a number of directives promoting renewable energy sources, including wind energy. [5,6] Renewable energy targets and directives provide incentives for individual countries to develop wind energy systems. These directives require individual countries to develop action plans and targets for renewable energy development and set targets so that renewable energy provides for 20% of all energy consumption by 2020. [5,6]

The European Union advocates for increases in renewable energy, but emphasizes that it should be added in an environmentally responsible matter. As early as 1985, the Council of European Communities (now within the European Union) published a directive requiring countries to complete an environmental impact assessment (EIA) for major development

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[4] World Wind Energy Association (WWEA). (2010). World wind energy report 2010. Retrieved from http://www.wwindea.org/home/images/stories/pdfs/worldwindenergyreport2010_s.pdf

[5] European Union. (n.d.). Europa: Summaries of legislation: Renewable energy. Retrieved from http://europa.eu/legislation_summaries/energy/renewable_energy/index_en.htm

[6] European Union. (n.d.). Europa: Summaries of legislation: Renewable energy. Retrieved from http://europa.eu/legislation_summaries/energy/renewable_energy/index_en.htm

projects.[7] This directive was amended to include wind turbines/wind facilities, but left it to the countries to determine which wind energy projects required an EIA based on their size and location.[8] According to the directive, the EIA must include information on potential impacts to humans, wildlife, landscape, air and water quality, the earth and plants, and historical or important sites.[7,8] The European Union also has published a directive regarding environmental noise.[8] While this does not specifically mention noise from wind turbines, it requires that all countries assess noise levels from infrastructure and transport systems and develop an action plan to set noise limits and mitigate problems.[9]

The World Health Organization Regional Office for Europe has published recommended noise limits of 40 dB(A) for the average nighttime noise outside a dwelling, which translates to a noise limit of 30 dB(A) inside a bedroom.[10] These limits are based on the noise levels when a person's quality of sleep is uninterrupted by noise; above these limits, people have a lower amount and quality of sleep which can lead to major health issues such as cardiovascular disease. The World Health Organization Regional Office for Europe has also recommended an average daytime noise level less than 35 dB(A) inside a classroom for a proper learning setting. The World Health Organization noise limits, especially the nighttime noise limits, are often referred to by many European countries as the basis for their own noise regulations.[10]

Germany

Germany's noise and shadow flicker policies regarding wind turbines are often referred to by other countries and wind associations, especially their policy regarding shadow flicker. However, Germany has no requirements or recommendations for wind turbine setback distances from residences. The "Federal Emission Control Act" calls for the protection of people, animals, and the environment from harmful air pollution, lighting, shadows, noise, and vibration.[11] Along with this law, the "Technical Instructions on Noise Abatement (TA Noise)" was published to establish noise limits specific to settings and noise measurement techniques.[12] The noise limits range from 35-50 dB(A) at night and from 45-70 dB(A) during the day, and depend on whether the area is primarily residential or commercial.[12]

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[7] The Council of the European Communities. (1985). Council Directive of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment (85/337/EEC). *Official Journal of the European Communities, L 175/40*. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1985:175:0040:0048:EN:PDF

[8] The Council of the European Communities. (1997). Council Directive 97/11/EC of 3 March 1997 amending Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment. *Official Journal of the European Communities, L 73/5*. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1997:073:0005:0015:EN:PDF

[9] The European Parliament and the Council of the European Union. (2002). Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise. *Official Journal of the European Communities, L 189/12*. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:189:0012:0025:EN:PDF

[10] World Health Organization: Regional Office for Europe. (2011). Noise: Facts and figures. Retrieved from http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/noise/facts-and-figures

[11] Bundesministerium der Justiz. (2011). Law on protection against harmful environmental effects of air pollution, noise, vibration and similar phenomena (Federal Emission Control Act- BImSchG). Retrieved from http://www.gesetze-im-internet.de/bimschg/index.html

[12] Bundesministerium der Justiz. (2000). Technische anleitung zum schutz gegen lärm (TA Lärm) [Sixth general administrative provision on the Federal Pollution Control Act (Technical instructions on noise abatement: Noise TA)]. Retrieved from http://www.umweltbundesamt.de/laermprobleme/publikationen/talaerm.pdf

The German States Committee for Pollution Control has adopted a document titled "Information on Identifying and Assessing the Optical Emissions from Wind Turbines (WEA-shadow-notes)."[13] This document identifies a limit to exposure to shadow flicker. Shadow flicker at residences, learning spaces, workplaces, and health care settings cannot exceed 30 minutes/day or 30 hours/year for astronomical maximum shading duration, or worst case scenario. In addition, actual amounts of shadow flicker at these locations cannot exceed 8 hours/year. If setback distances are not enough to reduce shadow flicker exposure to these limits, the wind turbines may be turned off during periods where shadow flicker is an issue.[13] Case laws also exists stating these shadow flicker limits.[14]

The German states and local governments are responsible for creating guidelines or requirements determining wind turbine siting and setbacks. However, according to German planning and building laws, state policies cannot be overly restrictive and must allow 20% of areas favorable to wind energy to remain open for wind facility development.[14] Many German state governments recommend a 1000- meter (3,281- foot) wind turbine setback from residences, but minimum setbacks may be as small as 300 meters (984 feet).[15,16] All wind energy projects are assessed before development, with wind facilities of 3-5 turbines requiring screening, 6-19 turbines requiring screening and evaluation, and 20 or more turbines entailing a full Environmental Impact Assessment.[17]

Germany's shadow flicker limits are referred to in a large number of government and wind energy association documents worldwide. However, few of these documents refer back to the original limits; they instead simply refer to other countries or associations who refer to the original German regulation. For this reason, there is much confusion about what Germany's shadow flicker regulations are, with the regulations being portrayed as case law, federal law, state or local law, or simply a recommendation at the federal or state level. The maximum 30 minutes/day or 30 hours/year for worst case scenario, and the 8 hours/year actual amounts of shadow flicker are a nationwide requirement in Germany as they are now part of the "Federal Emission Control Act (BLmSchG)," but have been used in case law and state and federal standards as well.[18,19]

One thing that may be contributing to the confusion regarding shadow flicker regulations is the term disco effect. This term was used in Germany when turbines were painted with reflective paint and therefore reflected light at people's homes, much like a disco ball. Many German regulations were created to mitigate this problem before all turbine paint was switched to a matte, non-reflective paint that solved the problem. When translating documents, the descriptions of shadow flicker and disco effect are very similar, leaving the possibility that old regulations for disco effect are being read as laws for shadow flicker. [20]

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[13] States Committee for Pollution Control (LAI). (2008). Information on identifying and assessing the optical emissions from wind turbines (WEA-shadow-notes). Retrieved from http://www.lung.mv-regierung.de/dateien/wea/schattenwurf/hinweise.pdf

[14] (Nicola Saccà, personal communication, June 24, 2011).

[15] (Dania Röpke, personal communication, August 18, 2011).

[16] (Christoph Brand, personal communication, August 17, 2011).

[17] Bundesministerium der Justiz. (2010). Anlage 1 liste "UVP-pflichtige Vorhaben" [Appendix 1 list "projects subject to EIA"]. Retrieved from http://www.gesetze-im-internet.de/uvpg/anlage_1_62.html

[18] (Dania Röpke, personal communication, August 31, 2011).

[19] (Johannes Pohl, personal communication, August 30, 2011).

[20] (Daniela Degen-Rosenberg, personal communication, August 25, 2011).

There have been two studies done in Germany regarding shadow flicker. [21,22] The first study, done in 1999, interviewed over 200 participants living near wind turbines on shadow flicker exposure, stress, behaviors, and coping. [21] The researchers found increased levels of actual shadow flicker exposure time correlated with increased stress levels and negative effects, with those experiencing over 15 hours of actual shadow flicker having decreased quality of life and high levels of daily annoyance. [21] These results influenced German recommendations including the WEA-shadow-notes.[23] However, one of the researchers stated that the stress levels and annoyance increased as the distance to the turbines decreased in all directions, not only the directions where shadow flicker occurs due to sunset/sunrise. This implies that the noise from wind turbines has a greater impact on stress levels than shadow flicker.[24]

Saarland.

Saarland has no wind turbine setbacks from residences, but goes by the German standards limiting noise emissions to determine how far wind turbines should be from residences.[25] Based on these noise limits, turbines are usually placed a minimum of 550 and 850 meters (1,894-2,789 feet) from homes, depending on their size. If residences within these distances from turbines experience more shadow flicker than allowed under the German standard, additional setback distances may be enforced. Individual communities are allowed to develop further restrictions to mitigate landscape and other concerns. However, additional community criteria cannot be overly restrictive according to German building laws. Twenty percent of areas with wind conditions favorable to wind energy must remain open for turbine development.[25]

Lower Saxony.

In Lower Saxony, wind facilities must go through a spatial planning process prior to development that looks at nature and landscape, safety concerns, and distance from other buildings.[26] The state usually recommends a 1,000-meter (3,281-foot) wind turbine setback distance from residences, but this is not a requirement and counties make the final decision. Setbacks are often determined on a case-by-case basis, with consideration given to the landscape up to 5,000 meters (16,404 feet) away from wind turbines.[27] Usually German noise standards

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[21] Pohl, J, Faul, F, & Mausfeld, R. (1999). Belästigung durch periodischen schattenwurf von windenergieanlagen [Annoyance caused by periodic shadow casting (or shadow flickering) of wind turbines]. Retrieved from http://cvi.se/uploads/pdf/Kunskapsdatabas%20miljo/Ljud%20och%20Skuggor/Skuggor/Utredningar/Feldstudie.pdf

[22] Pohl, J, Faul, F, & Mausfeld, R. (2000). Belästigung durch periodischen schattenwurf von windenergieanlagen: Laborpilotstudie [Harassment by periodic shadow of wind turbines: Laboratory pilot study]. Retrieved from http://cvi.se/uploads/pdf/Kunskapsdatabas%20miljo/Ljud%20och%20Skuggor/Skuggor/Utredningar/Laborstudie%20Schattenwurf.pdf

[23] (Johannes Pohl, personal communication, August 25, 2011).

[24](Rainer Mausfeld, personal communication, August 25, 2011).

[25](Nicola Saccà, personal communication, June 24, 2011).

[26] (Lars Bobzien, personal communication, June 28, 2011).

[27] Lower Saxony Ministry for Rural Areas, Food, Agriculture and Consumer Protection. (2004). Regional planning; recommendations for designation of priority areas for the suitability or wind energy. (MI of 11.7.1996 d. RdErl., Az 39.1-32346/8.4). Retrieved from http://www.zgb.de/barrierefrei/misc/rechtsgundlagen/rechtsgrundlagen_r/Windenergieerlass.pdf

determine the final setback distances, so noise measurements are required to ensure compliance with noise limits.[26]

Thuringia.

Thuringia determines wind turbine setbacks through the permitting process, the Germany emission laws regarding possible noise and shadow impacts, the German building law, and regional planning legislation.[28,29] The Thuringian Ministry of Construction, Land Development and Traffic has recommended that wind turbines be located at least 1,000 meters (3,281 feet) from residences and historical and recreational areas. This distance was determined from court cases and previous building experiences. However, this distance is only a recommendation, and the emission control law is used on a case-by-case basis to determine final setback distances.[28,29]

Hesse.

Hesse has developed recommendations of 1,000-meter (3,281-foot) wind turbine setbacks from residential areas.[30, 31] This distance may be reduced if the wind turbine meets noise emission standards and is near individual homes rather than a residential area. This setback recommendation is based on noise, shadow flicker, and light effects as well as public perception.[30, 31]

Bremen.

Bremen does not have any guidelines or requirements regarding wind turbine setbacks from residences, but rather relies on the German noise limits to establish distances between dwellings and wind turbines.[32] These noise limits were established based on scientific research on noise and human health and consideration for the living environment of people near wind turbines.[32] In practice, these noise regulations usually result in a setback distance of around 500 meters (1,640 feet) from residences, but this distance may be less if the wind turbines are located in an already noisy area. Shadow flicker is also a concern within Bremen, but is controlled by the existing German regulations that limit shadow flicker exposure to 30 minutes per day and eight hours of actual exposure per year.[32] In order to facilitate wind energy development, priority areas for the development of wind facilities have been identified based on wind speeds and existing residences and environmental areas.[33]

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[28] (Dirk Otto, personal communication, June 29, 2011).

[29] Thuringian Ministry of Construction, State Development and Transport. (2005). Recommendation for the continuation of the regional plans the designation of priority areas, "wind energy", which also the effect of suitable sites have. Retrieved from http://www.naturschutzstandards-erneuerbarer-energien.de/images/literatur/thueringen_handlungsempfehlung-ausweisung[1].pdf

[30](Klaus Gütling, personal communication, June 30, 2011).

[31] Hessian Ministry of Economy, Transport and Regional Development. (2010). 487: Recommendations of the Ministry of Economy, Transport and Regional Development and the Ministry of Environment, Energy, Agriculture and Consumer Protection at intervals of regionally significant wind turbines to legitimate spaces and facilities. Retrieved from http://www.hochtaunuskreis.de/htkmedia/Benutzerordner/60_00/Umwelt/Schwerpunkt/Windenergie/Ausgabe_22_2010-p-7626.pdf

[32] (Kai Demske, personal communication, July 26, 2011).

[33] Senator for Women, Health, Youth, Social and Environmental Protection, & Senator for Construction, Transport and Urban development. (1995). Framework-priority areas for wind energy utilization in the city of

Schleswig-Holstein.

In a document called "Principles for Planning of Wind Turbines", Schleswig-Holstein identifies recommended wind turbine setback distances from various settings.[34] Wind turbines should be setback 1,000 meters (3,281 feet) from towns and vacation areas, 500 meters (1,640 feet) from rural areas with a number of homes, and 300 meters (985 feet) from rural areas with 1-4 dwellings. For safety concerns, wind turbines should be located at a distance of 50-100 meters (164- 328 feet) from roads, railways, radio communication, and power lines. In addition, wind turbines should be set back 200- 500 meters (656- 1,640 feet) from waterways and areas of environmental importance. These setbacks were developed out of public concern for possible impacts to the landscape, health and quality of life, historical and cultural areas, the environment, and tourism.[34]

Hamburg.

Hamburg has published a document entitled "Exclusion Zones for Wind Turbines in Hamburg," which outlines wind turbine setback requirements from many settings, but does not provide rationale for their setbacks.[35] Wind turbines must be setback 300 meters (985 feet) from individual dwellings and 500 meters (1,640 feet) from residential areas. Turbines are also required to be located 50-100 meters (164- 328 feet) from the nearest roads, railways, power lines, radio transmitters, and property lines. To protect the environment, turbines must be set back a distance of 200-500 meters (656-1,640 feet) from forests, wetlands, bird and bat areas, and other areas of environmental concern.[35]

Saxony.

Saxony has published an extensive document entitled: "Wind turbines: Information for Property Owners and Farmers."[36] This document determines wind turbine setback distances differently than other German states. Instead of determining setback distances based on the number of nearby residences, Saxony determines setbacks based on the number of turbines. Individual turbines should be located a distance of 300 meters (985 feet) from nearby buildings, and wind facilities should be set back 500 meters (1,640 feet) from buildings. This appears to be a recommendation rather than a requirement, and it is unclear whether this recommendation applies to all structures or just residences. Minimally, wind turbines must be set back a distance equal to their height from nearby structures, but it appears that possible effects should be examined out to 1500 meters (4,921 feet). This document states compliance with the German

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Bremen. Retrieved from http://www.naturschutzstandards-erneuerbarer-energien.de/images/literatur/Bremen_Rahmenkonzept_Windenergienutzung_1996[1].pdf

[34]The Interior, the Minister for Finance and Energy, Minister for Nature and Environment, & the Prime Minister (State Planning Authority). (2003). Principles for planning of wind turbines (Official Gazette Schl.-H 1995 p. 478, (Official Gazette Schl. HS-893)). Retrieved from http://www.Schleswig-holstein.de/cae/servlet/contentblob/826358/publicationfile/Grundsaetze_Planung_WEA.pdf

[35]Hamburg Ministry of Urban Development and Environment. (2010). Exclusion zones for wind turbines in Hamburg. Retrieved from http://www.hamburg.de/contentblob/2642064/data/f-xx-xx-windenergieanlagen-ausschlussgebiete.pdf

[36] Saxon State Ministry of Environment and Agriculture. (n.d.). Wind turbines: Information for property owners and farmers. Retrieved from http://www.smul.sachsen.de/lfl/publikationen/download/306_2.pdf

noise and shadow flicker requirements must be met, and mentions a court case allowing for noise limits of 45 dB(A) at night and 60 dB(A) during the day at nearby residences. These planning guidelines are based on concerns of possible impacts to the environment, landscape, shadow flicker, and noise. [36]

Mecklenburg-Vorpommern.

Mecklenburg-Vorpommern has not published any documents regarding wind turbine setbacks, but has rather posted links to two documents from the States Committee for Pollution Control (LAI). The first of these documents is entitled "Information for Sound Emission from Wind Turbines," and highlights how to measure sound emissions from wind turbines to meet German requirements.[37] The second document is the Information on identifying and assessing the optical emissions from wind turbines (WEA-shadow-notes), or the German standard for shadow flicker limits. [38]

Rhineland-Palatinate.

Rhineland-Palatinate recommends a wind turbine setback distance of 1,000 meters (3,281 feet) from nearby residences.[39] This setback is based on a court decision to avoid negative impacts to residential areas. Distances to mitigate noise and shadow flicker are also determined before wind facility development.[39] Rhineland-Palatinate had also published "Notes to Assess the Acceptability of Wind Turbines." [40] This document discusses priority areas for wind development, setback distances, and assessment of wind energy developments. This document recommends a minimum wind turbine setback distance of 400 meters (1,312 feet) from individual homes, or a distance necessary to meet the German noise limit requirements. This document also states that all wind energy developments are prohibited from environmentally sensitive areas, but does not define what these areas include. Recommendations were developed based on impact concerns for noise, shadow flicker, landscape, and the environment.[40]

Berlin.

Berlin has no policies or guidelines for wind turbine development.[41] Only one turbine has been erected due to the density of the population. This turbine was erected in accordance with national laws and general regional laws concerning land and building development, safety, and noise.[41]

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[37] States Committee for Pollution Control (LAI). (2005). Information for sound immission from wind turbines. Retrieved from http://www.lung.nv-regierung.de/dateien/wea_schallimmissionsschutz.pdf

[38] [2]States Committee for Pollution Control (LAI). 92..8). Information on identifying and assessing the optical emissions from wind turbines (WEA-shadow-notes). Retrieved from http://www.lung.mv-regierung.de/dateien/wea_schattenwurf_hinweise.pdf

[39] (Ulrich Gallent, personal communication, July 13, 2011).

[40] Ministry of Finance, the Ministry of Inners and Sport, the Ministry of Economy, Transport, Agriculture and Viticulture, & the Ministry of Environment and Forests. (2006). Notes to assess the acceptability of wind turbines. Retrieved from http://www.ism.rlp.de/fileadmin/ism/downloads/landesplanung/strukturen_der_planung/Hinweis_zur_Beurteilung_von_Windenergieanlagen.pdf

[41] (Günther Sauer, personal communication, July 17, 2011).

Spain

In Spain, there are national noise laws, the "Law 37/2003" on noise, and the "Royal Degree 1513/2005" that implements Law 37/2003.[42, 43] These noise laws are general and not specific to wind turbines or any other form of development, but require that regional governments within Spain determine and measure noise limits.[44] Regional governments are responsible for determining wind turbine setback distances as well, but it is recommended that wind turbines are setback 500 meters (1,640 feet) from residences and towns, and 120 meters (394 feet) from roads and power lines. These distances are recommended due to safety concerns as well as noise limits. At a minimum, the regional governments' wind turbine policies should ensure that noise doesn't exceed 50 dB(A) near residences, the World Health Organization's maximum noise level before health and quality of life are negatively impacted. [44]

For a standard wind turbine, 300 meters (984 feet) is considered a large enough setback to ensure that noise levels at residences remains below 45 dB(A), so this setback distance is recommended as the minimum acceptable setback distance.[45] At the regional level, however, this doesn't always seem to be followed. In the Canary Islands, the minimum setback distance is 150 meters (492 feet) from residences and 250 meters (820 feet) from towns, but wind turbines cannot be installed in environmentally sensitive areas.[46] There are other factors taken into consideration for wind turbine siting, including visual impact, communication and aviation systems, and bird flight paths, but there are no national policies or recommendations for these areas.[47]

Italy

While Italy has the sixth largest onshore wind capacity in the world with 5,797 megawatts, it does not appear to have any national policies or recommendations relevant to wind turbine setbacks; in fact, it has very little information available about renewable energy or wind energy. Italy does not have any regulations or guidelines regarding shadow flicker.[48]

France

France has strict noise limits and other regulations for wind turbines. All wind facilities and turbines over 50 meters (164 feet) in total height are subject to a public inquiry and an

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[42] King Juan Carlos I & Spanish Parliament. (2003). Law 37/2003 of November 17, Noise. Retrieved from http://sanidadambiental.com/wp-content/uploads/2009/05/ley37-03-del-ruido.pdf

[43] King Juan Carlos I & Spanish Parliament. (2005). Royal Decree 1513/2005 of 16 December BRE, which implements Law 37/2003, of November 17, Noise, regarding the assessment and management of environmental noise. Retrieved from http://sanidadambiental.com/wp-content/uploads/2009/05/rd1513-2005-evaluacion-y-gestion-ruido.pdf

[44] World Health Organization: Regional Office for Europe. (2011). Noise: Facts and figures. Retrieved from http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/noise/facts-and-figures

[45] (Juan Ramon Ayuso Ortiz, personal communication, August 25, 2011).

[46] (Tomas Cambreleng Lundager, personal communication, September 12, 2011).

[47] Ministerio de Industria, Turismo y Comercio & Institute para la Diversificacion y Ahorro de la Energia. (n.d.). Manuales de energias renovables 3: Energia eolica [Renewable energy manual 3: Wind energy]. Retrieved from http://www.idae.es/index/php/mpd.documentos/mem.descarga?file=/documentos_10374_Energia_eolica_06_d9231f5c.pdf

[48] (Karina Lindvig, personal communication, September 27, 2011).

environmental impact assessment for potential landscape and noise level effects.[49] Turbines over 12 meters (39 feet) in height need a building permit. France's noise limits are identified in their "Code of Public Health" and require background noise levels to be at or below 25 dB within residences around wind turbines. This noise limit of 25 dB within residences is the same noise limit used for general neighborhood noise regulations.[49] In addition, beginning in July, 2011, wind turbines are required to be located at least 500 meters (1,640 feet) from all residential areas.[49]

These wind turbine restrictions may stem from a 2006 report by the French National Academy of Medicine, which stated that wind turbines do not pose a health risk due to shadow flicker or infrasound but do pose a risk due to noise. This report also recommended that France should implement policies requiring all turbines to be sited no closer than 1500 meters (4,921 feet) from homes, but this has not been put into place.[50] France has also developed areas specifically for wind energy development, or ZDE's.[51] ZDE's are determined based on wind energy potential and impacts to the environment, safety, historical areas, noise, and the landscape. Wind energy systems built outside of a ZDE are not eligible for the renewable portfolio standards set by France to meet its renewable energy goals.[51]

Canada

At the national level, Canada does not have any requirements regarding wind turbine setbacks from residences, as setback requirements are decided at the provincial level instead of the federal.[52] The Canadian Wind Energy Association (CanWEA) has developed some guidelines regarding setback distances within certain provinces, but no overall plan.[53] Some provinces, such as Ontario, have highly developed regulations of wind facilities.[53] Depending on the province or territory; municipalities have varied amounts of control over wind facility siting.[52] The federal government only becomes involved during an environmental review if the project involves areas that fall under federal jurisdiction. If the federal government becomes involved, siting is done on a case-by-case basis, with Health Canada experts advising on noise effects based on World Health Organization guidelines.[54]

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[49] Ministere De L'Ecologie, du Developpement Durable, des Transports et du Logement. (2010). Energy and climate: Wind power. Retrieved from http://www.developpement-durable.gouv.fr/-Energie-eolienne-.html

[50] National Academy of Medicine. (2006). The impact of wind turbine operation on human health. Retrieved from http://www.developpement-durable.gouv.fr/IMG/pdf/eoienne_sante_2006_academie_medecine.pdf

[51] Ministere De L'Ecologie, du Developpement Durable, des Transports et du Logement. (2010). Questions/answers: ZDE. Retrieved from http://www.developpement-durable.gouv.fr/IMG/pdf/FAQ_ZDE.pdf

[52] (Denis Zborowski, personal communication, June 13, 2011).

[53] Canadian Wind Energy Association (CanWEA). (2007). CanWEA position on setbacks for large-scale wind turbines in rural areas (MOE class 3) in Ontario. Retrieved from http://www.canwea.ca/images/uploads/File/FINAL-CanWEAPositionOnSetbacks-2007-09-28.pdf

[54] World Health Organization: Regional Office for Europe. (2011). Noise: Facts and figures. Retrieved from http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/noise/facts-and-figures

Ontario.

CanWEA, the Canadian Wind Energy Association, has developed recommendations of setback distances specifically for wind turbines in rural Ontario.[55] This document addressed issues regarding turbine and blade failure, ice throw, noise, environmental impacts, and interruption of communication systems. Based on a review of literature and existing regulations, CanWEA recommended setbacks to mitigate these concerns. To reduce environmental and communication system impacts, setbacks should be based on site-specific studies and existing publications, the environmental screening process, and Radio Advisory Board of Canada guidance. Public roads and property lines should be located no closer than the length of one turbine blade plus 10 meters (32 feet), to reduce the small levels of risk from ice throw or turbine/blade failure.[55] For determining setback distances from towns and residences, CanWEA referred to the sound regulations identified in the Ontario Ministry of Environment's "NPC-232 Regulations Governing Appropriate Sound Level Limits in Class 3 Areas (Rural)."[56]

The Ontario Ministry of the Environment has created documents that define general noise limits for rural and urban areas as well as guidelines for achieving those limits with wind facility development. One of these documents is the" Sound Level Limits for Stationary Sources in Class 3 Areas (Rural)." This document is the publication NPC-232 referred to in CanWEA's report, and is applicable to many different types of stationary structures.[56] The second document, "Noise Guidelines for Wind Farms," explains how the sound level limits identified in NPC-232 may be applied to wind turbines.[57] These two documents indicate that sounds from wind turbines should match the background sound levels specific to an area. These sound levels vary with the time of day and variances in existing sounds such as the speed of wind. In a rural area, sound level limits from wind turbines range from 40 to 51 db(A) at wind speeds of 4 to 10 meters per second (13 to 32 feet per second), respectively.[57]

Ontario has well-developed turbine setback regulations. It classifies wind facilities according to their capacity level and sound produced, ranging from Class 1 with a less than a 3 kW capacity and any sound level, to Class 5 with greater than a 50 kW capacity and greater than 102 sound level. [56, 57] For wind facilities ranked class three or above, all turbines must be one blade length plus 10 meters (32 feet) away from public roads/railways, and one turbine height away from property boundaries. All turbines at wind facilities ranked class four or higher must be located at least 550 meters (1,804 feet) away from all residences, workplaces, and recreational areas, unless the background noise levels are greater than 40 dB(A) before turbines are erected, in which case the setback distance may be decreased.[56, 57]

To address health concerns from the public, the Chief Medical Officer of Health (CMOH) for Ontario compiled a report describing the results from scientific studies on possible

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[55] Canadian Wind Energy Association (CanWEA). (2007). CanWEA position on setbacks for large-scale wind turbines in rural areas (MOE class 3) in Ontario. Retrieved from http://www.canwea.ca/images/uploads/File/FINAL-CanWEAPositionOnSetbacks-2007-09-28.pdf

[56] Ontario Ministry of the Environment (MOE). (1995). Sound level limits for stationary sources in class 3 areas (rural) (Publication NPC-232). Retrieved from http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/std01_079359.pdf

[57] Ontario Ministry of the Environment (MOE). (2008). Noise guidelines for wind farms. Retrieved from http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/std01_079435.pdf

health impacts from living in the proximity of wind turbines.[58] This report examined existing studies from 1970 until 2010 from peer-reviewed journals and organizations such as the World Health Organization. Based on their research, they determined that there is no proven evidence of a link between wind turbines and negative health effects, although some people may experience annoyance from the noise or shadow flicker and a few people have reported symptoms.[58] Based on this research the CMOH determined that the existing Ontario turbine setback requirements are adequate to protect health.[58] This determination is reinforced by a recent court case, where the Ontario Divisional Court upheld the setback distances in Ontario, stating that the setbacks were based on Ontario's" Statement of Environmental Values," existing research, and public input.[59]

New Brunswick.

New Brunswick has published a report on "Model Wind Turbine Provisions and Best Practices for New Brunswick Municipalities, Rural Communities and Unincorporated Areas." [60] This report identifies examples of policies for municipalities to develop wind turbine siting guidelines. While many of these policy examples are from other Canadian provinces, it does identify some wind turbine noise limits in New Brunswick. In New Brunswick, noise limits vary with wind speed, ranging from 40 dB(A) at wind speeds below 7 meters per second (23 feet/second), to 53 dB(A) at wind speeds above 10 meters per second (33 feet/second). Companies must demonstrate that their wind projects will meet these noise requirements for all homes and recreational areas within 1 km, these are primarily used to determine setback distances for privately owned land.

Brunswick has a policy regarding setbacks for crown lands, or federal or province-controlled lands, but not for privately owned land. On crown lands, wind turbines must be located at a distance of 150 meters (492 feet) or 1.5x the total turbine height from all water and industrial areas. Turbines on crown lands must also be located 500 meters (1,640 feet) or 5x the turbine height from roads, communication towers, and recreational or residential areas, and 1,000 meters (3,281 feet) from endangered species habitat. If municipalities have additional requirements in addition to the requirements on crown lands, these must be obeyed as well. New Brunswick is in the process of developing additional guidelines for all wind projects in the province, but these have not been completed as of this document.[60]

Prince Edward Island.

Prince Edward Island has published a number of planning regulations that pertain to wind facility development.[61] These regulations define minimum distances turbines may be located

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[58] Chief Medical Officer of Health (CMOH) of Ontario. (2010). The potential health impact of wind turbines (Chief medical officer of health (CMOH) report). Retrieved from http://www.health.gov.on.ca.en/public/publications/ministry_reports/wind_turbine/wind_turbine.pdf

[59] Canadian Wind Energy Association (CanWEA). (2011). Media centre: 03/03/2011 Court upholds current regulations for wind turbine setbacks Ontario; Divisional court dismisses claim government ignored its own Statement of Environmental Values (SEV) in developing setback regulation. Retrieved from http://www.canwea.ca/media/release/release_e.php?newsld=114

[60] New Brunswick Department of Energy. (2008). Report: Model wind turbine provisions and best practices for New Brunswick municipalities, rural communities and unincorporated areas. Retrieved from http://www.gnb.ca/0085/pdf/NBwindEnergy.pdf

[61] Prince Edward Island Department of Environment, Energy and Forestry. (2010). Wind turbine approval. Retrieved from http://www.gov.pe.ca/eef/index.php3?number=1029405&lang=E

from nearby property lines, residences, and roads. The regulations state that wind turbines must be set back a minimum of 3 times the total height from all residences, unless the developer owns the property. If the developer owns the property, the wind turbine must be located at a distance at least the height of the wind turbine from residences on the property, and 3 times the turbine height from residences on bordering properties. In addition, turbines must be set back a minimum distance of the turbine height from all property boundaries and public roads. These restrictions were developed based on possible impacts regarding the environment and public health and safety concerns.[61]

Manitoba.

Manitoba regulates wind facility development primarily through two acts, the "Environmental Act" and the "Planning Act."[62] The Environmental Act primarily deals with impacts to wildlife and the environment, including noise pollution.[63] Wind facility developers must demonstrate compliance through an environmental assessment with Manitoba's noise limits. For wind facilities, Manitoba uses the noise limit scale developed by the Canadian Wind Energy Association, with limits ranging from 40 dB(A) at wind speeds of 4 meters per second (13 feet/second) to 53 dB(A) at 11 meters per second (36 feet/second). Based on these sound limits, Manitoba suggests a 500-550 meter (1,640- 1,804 foot) wind turbine setback from homes.[2] In practice, municipalities set setback distances ranging from 300-800 meters (984-2,625 feet) from residences.[62]

Manitoba's Planning Act provides recommendations for municipalities for developing zoning requirements.[63] The act recommends a 500-550 meter (1,640- 1,804 foot) setback from dwellings for noise concerns, 1.5x the total turbine height setback from property lines and roads in case of blade failure, and a 30 meter (98 foot) setback from water sources to prevent pollution. In addition, Manitoba recommends that turbines be painted a neutral color without advertising, minimal lighting be used as required by aviation controls, and power lines be buried to reduce the visual impact on a community.[2] Additional rules are relevant for wind energy facilities on crown land (governmentally-controlled land) in Manitoba.[64]

Alberta.

Wind energy policies in Alberta come from the Alberta Utilities Commission (AUC).[65] There are two relevant rules relating to wind energy development. In a rule regarding applications for energy facilities, it states that wind developers must provide evidence of approval from the Alberta Sustainable Resource Development, NAV Canada, Transport Canada, and Alberta Transportation if a turbine will be within 300 meters (984 feet) of a highway.[66] A wind energy developer must also indicate each turbine's exact location and surrounding

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[62] (Rick Halas, personal communication, August 15, 2011).

[63] EDS Consulting. (2009). Final report to Manitoba Intergovernmental Affairs on land use planning for wind energy systems in Manitoba. Retrieved from http://www.gov.mb.ca.ia.programs/land_use_dev/pef/wind_energy_guidelines.pdf

[64] Manitoba Innovation, Energy, and Mines. Crown land policy and wind farms. Retrieved from http://www.manitoba.ca/iem/energy/wind/files/crown_land_policy_wind_farms.pdf

[65] (Ian McKay, personal communication, July 28, 2011).

[66] Alberta Utilities Commission. (2009). *Applications for power plants, substations, transmission lines, and industrial system designations* (Rule 007). Retrieved from http://www.auc.ab.ca/acts-regulations-and-auc-rules/rules/Documents/Rule007.pdf

residences and land use, and provide evidence that there is minimal risk of possible stray voltage. In addition, those applying to develop wind facilities must demonstrate public participation, involving people living within 800-2000 meters (2,625- 6,562 feet) depending on the project. In this public participation, developers must provide project information, answer questions, respond to concerns, and provide alternatives or mitigation procedures.[66]

In addition, the AUC has published a rule on noise control near energy facilities.[67] For wind turbines, noise should be measured when wind speeds are 6-9 meters per second (20- 30 feet per second) at 15 meters (48 feet) from the most affected residence within 1.5 km. The night noise limits should remain between 40 and 56 dB(A) $L_{A\ eq}$, based on the number of other residences and existing infrastructure noise sources. For most wind energy locations, the night noise limits will probably fall between 40 and 46 dB(A) $L_{A\ eq}$. The day noise limits are 10 dB(A) above night limits. Low frequency noise should also be measured with C-weighted sound measurements to ensure that low frequency noise is not excessive.[67]

Quebec.

Quebec has not established any requirements or recommendations for wind turbine setbacks from residences.[68] Municipalities determine requirements for wind facility developments, resulting in a range of setback distances. A 500 meter (1,640 foot) setback distance seems to be the most common required wind turbine setback among municipalities.[68]

Yukon.

The Yukon does not have any rules or guidelines regarding wind facilities, primarily due to the fact it is a sparsely-populated area, and wind turbines are thus easily located far enough away from residences to no be an issue.[69]

Nova Scotia.

Nova Scotia has 284 MW of wind energy installed, but does not seem to have any policies or guidelines regarding wind facility development.

Newfoundland and Labrador.

Newfoundland and Labrador have 54MW of wind power installed, but do not seem to have any policies or guidelines regarding wind facility development.

United Kingdom

The United Kingdom has no statutory limits relating to the distance that wind turbines are placed from homes.[70] However, England, Scotland, and Wales do have some recommendations in place regarding wind turbine siting. Scotland suggests that wind turbines be located two kilometers (1.24 miles) away from cities, towns, and villages to reduce the visual impact, but

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[67] Alberta Utilities Commission. (2011). *Noise control* (Rule 012). Retrieved from http://www.auc.ab.ca/acts-regulations-and-auc-rules/rules/Documents/Rule012.pdf

[68] (Mathieu Roy, personal communication, August 2, 2011).

[69] (Sean MacKinnon, personal communication, July 25, 2011).

[70] (Susan Bragoli, personal communication, June 21, 2011).

wind facilities are still judged on a case-by-case basis.[71] Wales recommends a setback distance of 500 meters (1,640 feet) from homes to avoid large increases in noise levels, but states that this may be increased or decreased based on the levels of existing background noise. Wind turbines should not increase residential night and day noise levels more than 5 dB(A) above background.[71]

England does not recommend or require any wind turbine setback distances from homes.[72] Appropriate distances between wind turbines and homes are determined based on the possible sound and visual consequences. For safety concerns, England identifies a setback distance from residences of the height of the turbine plus an additional 10% in case of structure failures.[71] Noise from wind facilities is compared to "ETSU-R-97," an assessment document created in 1997 that recommends noise be limited to 5 dB(A) above existing night and day background noise, with a fixed night limit of 43 dB(A) using $L_{A90,\,10\ min}$ or 45 dB(A) for properties benefitting financially from wind turbine development.[73] A penalty of up to 5 dB(A) lowering the noise limits may be added if a distinct tone is distinguishable. This same document discusses that the expected wind turbine noise levels from 350 meters (1,148 ft) away would range from 35-45 dB(A), implying a suggested distance of 350 meters.[73] However, the validity of this document is often questioned and a study of its application has been commissioned for 2011.[70] In addition, there have been several attempts to pass a bill mandating a much larger wind turbine setback distance from homes.[74]

Portugal

In Portugal, noise limits are the primary means of determining wind turbine setback distances.[75] There is a general noise law that does not specifically identify noise limits for wind turbines, but rather establishes noise limits for sensitive (residential) areas and mixed commercial and residential areas. [76] Noise within sensitive areas should be limited to 45 dB(A) during the night, and 55 dB(A) during the day. Areas with both commercial and residential sections have noise limits 10 decibels above those for the sensitive areas.[76] These noise limits are

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[71] Barclay, C. (2010). Wind farms- Distance from housing (Library House of Commons Standard Note: SN/SC/5221). Retrieved from http://nottingham.ac.uk/renewableenergyproject/documents/houseofcommonsbriefingpaper18nov2010.pdf

[72] Department of Energy and Climate Change. (2011). Onshore wind Q & A. Retrieved from http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/Energy%20mix/Renewable%20energy/explained/wind/1302-onshore-wind-q-a.pdf

[73] Working Group on Noise from Wind Turbines, The. (1996). The assessment and rating of noise from wind farms: Final report (ETSU-R-97). Retrieved from http://www.semantise.com/~lewiswindfarms/FOV1-00021BAE/FOV1-00021BD2/1996:00:00%20ETSU-R-97%20-%20Exec%20Summary.pdf?FCItemID=S000C081A

[74] House of Lords. (2011). Column 485 House of Lords Friday, 10 June 2011: Wind turbines (minimum distance from residential premises) bill [HL]: Second reading. Retrieved from http://www.publications.parliament.uk/pa/ld201011/ldhansrd/text/110610-0001.htm#11061043000429

[75] (Marlene Loiverira das Neves, personal communication, August 30, 2011).

[76] Miniserio do Ambiente, do Ordenamento do Territorio e do Desenvolvimento Regional. (2007). Decreto-Lei n.o 9/2007 de 17 de Janeiro [Decree-Law No 9: 2007 17 January (General regulation of noise)]. Retrieved from http://dre.pt/pdf1s/2007/01/01200/03890398.pdf

used to determine setback distances for wind turbines, with a 200 meter (656 foot) setback appearing to be widely used. Although setback distances are determined based on noise legislation, communities have the ability to deny wind energy companies the permission to erect turbines near their community.[77]

Denmark

Denmark has the highest wind energy capacity per capita, per land area, and per GDP in the world.[78] In Denmark, it is recommended that wind turbine setback distances from building be at least 4 times the total height of the turbine.[79,80] This information is included in the "Wind Turbines in Denmark" booklet, published by the Danish Energy Agency, which includes extensive discussion of possible effects of wind turbines on their surroundings, including noise, shadow, reflection, and housing values.[80] It states that an Environmental Impact Assessment (EIA) will be carried out for all wind facilities involving turbines over 80 meters (262 feet) tall or more than three turbines. The EIA will check for both impacts for the environment as well as compliance with laws regarding wind energy.[80]

The Danish Energy Agency recommends that no house be exposed to shadow flicker more than 10 hours per year.[80] If the amount of shadow flicker exceeds the maximum recommended amount, the wind turbine owner may be required to place a timer on the turbines to shut them off during the times of the day subject to shadow flicker. Regarding turbine lighting, the Denmark's Civil Aviation Administration requires mandatory lights for airplanes on all turbines over 150 meters (492 feet) and on all turbines over 100 meters (328 feet) near airports and flight paths. These lights may possibly be viewed as a nuisance by residents, but are no different from lights on television or radio towers, and thus require no additional regulation.[80]

Noise from wind turbines is given special attention in Denmark. The Danish Ministry of the Environment created an "Order on Noise from Wind Turbines." [81] This amendment is legally binding and establishes noise limits for sparsely populated residential areas, built-up areas, and recreational areas ranging from 37-44 dB(A) for wind speeds at 6- 8 meters per second (20- 26 feet/second). The areas with greater occupation and recreational areas have lower limits for noise from wind turbines. The Danish Energy Agency report acknowledges that wind turbines emit both low frequency noise and infrasound, but these noises appear to be well under the legal limit and no more annoying than high frequency noises, and are thus not specifically addressed in relation to wind turbines.[82]

Municipalities are in charge of the planning for wind turbines up to 150 meters (492 feet) tall, with assistance from the Wind Turbine Secretariat in the Agency for Spatial and Environmental Planning.[80] The municipalities work closely with both members from the public

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[77] (Miguel Agostinho, personal communication, August 6, 2011).

[78] World Wind Energy Association (WWEA). (2010). World wind energy report 2010. Retrieved from http://www.wwindea.org/home/images/stories/pdfs/worldwindenergyreport2010_s.pdf

[79] (Pia C. Jensen, personal communication, June 14, 2011).

[80] Danish Energy Agency. (2009). Wind turbines in Denmark. Retrieved from http://www.ens.dk/da-dk/Sider/forside.aspx

[81] Danish Ministry of the Environment. (n.d.). Order on noise from wind turbines. Retrieved from http://www.retsinformation.dk/Forms/R0710.aspx?id=13020

[82] Danish Electronics, Light and Acoustics. (2010). Low frequency noise from large wind turbines. Retrieved from http://www.madebydelta.com/delta/Business_units/TC/Services+by+technology/Acoustics/Low+frequency+noise/Low+frequency+noise+from+large+wind+turbines.page

and wind turbine owners or sponsors. The municipalities create guidelines and requirements regarding turbine siting that fall within Danish law parameters and take into account residences, the environment, historical elements, the view, agriculture, and other factors.

Other than small turbines, no turbines may be constructed without the approval of the municipality. If a project involves more than three turbines or turbines more than 80 meters (262 feet) tall, an EIA must be completed for permitting. Even without an EIA, neighbors must be informed of the project ahead of time. In order to assist municipalities, a website is updated by the Wind Turbine Secretariat with frequently asked questions, a summary of siting issues, a model and time frame for the siting process, and existing governmental regulations. Typically, all wind turbines over 25 meters (82 feet) high must be placed at least four times their height from all residences. Generally, wind turbines are prohibited from locations within three kilometers (1.86 miles) of the coast unless special permission is granted due to the positive environment for wind energy. Areas with wide, open, flat spaces are generally considered better for wind facility development than areas with many hills, as large turbines do not overpower the existing landscape in a flat area. Municipalities often require grouping of wind turbines and geometric arrangements to reduce the visual impacts.[80]

People living within six times the total height of the wind turbine may request to have their property assessed for loss of value due to proximity of the wind turbines.[80] If the value of their property is determined to have decreased by a minimum of 1%, they may be reimbursed for their loss. The value of the property is assessed by experts in property value, and if they determine a significant decrease in the property value the wind facility developer is required to pay the difference. There are other incentives for developing wind facilities, including feed-in tariffs and the option for local residents to purchase the wind turbines.[80]

The Netherlands

There are several rules that determine how far wind turbines are located from residences.[83] A building permit is required in order to erect a large wind turbine. Developers must demonstrate that their future wind turbine will not exceed yearly average noise limits of 47 dB(A) during the day and 41 dB(A) during the night at the nearest dwelling.[84] This generally results in a wind turbine setback distance of 4x the height to the hub of the turbine form nearby homes.[84] There are also regulations regarding shadow flicker, but it is generally considered not to be a problem at a distance to reach the noise limit.[83]

There are also setback requirements of one rotor diameter to significantly reduce the chance of injury in case of turbine blade failure. Wind turbines must also cause no significant effects on birds, natural reserves, and protected landscapes. Setback distances are primarily determined by the noise limits, and the Netherlands government is intending to review their methods for measuring sound from wind turbines shortly.[83]

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[83] (Albert Jansen, personal communication, July 27, 2011).

[84] Netherlands Energy and Climate Division. (2011). Wet-en regelgeving: Besluit algemene regels voor inrichtingen milieubeheer geldend op 05-08-2011 [Laws and regulations: Decision rules for environmental management prevailing on 08.05.2011]. Retrieved from http://wetten.overheid.nl/BWBRoo22762/Hoofdstuk31035682/Afdeling32/323/Artikel1314a/geldigheidsdatum_05-08-2011

Sweden

Sweden has no national policies or recommendations regarding wind turbine setback distances from residences.[85, 86] However, Sweden does have guidelines for noise limits, which identify a 40 dB(A) sound limit near homes and are used to determine wind turbine setback distances.[3] In some cases where environment has low background noise, the sound limit may be lowered to 35 dB(A). A five dB(A) penalty may be invoked if the wind turbines emit specific tones. These sound limits are based on studies of the number of people highly annoyed by wind turbine noise at different sound levels.[87] Sweden has no guidelines pertaining to shadow flicker, but refers regional governments to Germany's policies regarding shadow flicker.[85, 86] The risk of ice being thrown from the wind turbines is also taken into consideration when determining setback distances.

Municipalities also adopt guidelines for wind turbine siting, including the distance to nearby residences.[85, 86] In northern Sweden, many municipalities have adopted a setback recommendation of 1000 meters (3,281 feet), but in southern Sweden where the population is dense, this is not feasible, and distances are determined by local conditions and the sound limits.[86] Counties often develop wind turbine setback recommendations for the municipalities, which seem to range from 400-1000 meters (1,312- 3,281 feet)from residences, but it is up to the municipalities to decide whether to use these recommendations.[1,2] All wind energy developments with 1-2 turbines up to 150 meters (492 feet) in height must inform the municipality, and all large wind facilities must obtain a permit before development.[88]

Australia

In Australia, the placement of wind turbines rests primarily with state and territory governments.[89] The federal government only gets involved when wind facilities may have an impact on endangered or migratory animals, major wetlands, or heritage sites. The Environment Protection and Heritage Council (EPHC) has published the National Wind Farm Development Guidelines Draft, which discusses the issues of noise, shadow flicker, landscape, and other impacts, but focuses more on how the states and territories should go about establishing guidelines rather than suggesting specific guidelines for wind turbine siting.[90] However, this document also lists existing limits at the state or territory level that apply to noise or shadow flicker. Only two states have addressed shadow flicker, with Victoria guidelines recommending no more than 30 hours per year shadow flicker exposure, and South Australia stating that shadow flicker must be considered to a distance of 500 meters (1,640 feet).[89]

According to the EPHC, New South Wales, South Australia, Tasmania, Victoria, and Western Australia all have general noise limits applicable to wind turbines.[90] New South Wales requires the $L_{A\,eq}$ for 10 minutes, or constant sound pressure level, to be less than or equal to 35 dB(A), with a 5dB penalty for tonality. Victoria has a noise level limit of 40 dB for $L_{A95,}$ with

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[85] (Eva Centeno Lopez, personal communication, August 22, 2011).
[86] (Bengt Larsen, personal communication, August 22, 2011).
[87] Natur Vards Verket. (2010). Ljud [Noise]. Retrieved from http://www.vindlov.se/sv/Steg-for-steg/Stora-anlaggningar/Inledande-skede/Halsa--sakerhet/Ljud/
[88] Natur Vards Verket. (2010). Detaljplan [Detailed plan]. Retrieved from http://www.vindlov.se/sv/Steg-for-steg/Stora-anlaggningar/Provningsprocessen/Detaljplan/
[89] (Jessica Rabone, personal communication, June 15, 2011).
[90] Environment Protection and Heritage Council (EPHC). (2010). National wind farm development guidelines: Draft July 2010. Retrieved from http://www.ephc.gov.au/node/449

5dB penalties for tonality, modulation, and impulsiveness, and requirements for measuring both nighttime and daytime noise. South Australia's policy is similar to Victoria's, with L_{A90} 35-40db and a 5dB tonality penalty. Tasmania judges wind facilities individually for noise limits, but applies a 5-10 dB penalty for low frequency noise, impulsiveness, tonality, or modulation. Western Australia has the strictest regulations, with an L_{A10} of 35dB, a 5-15 dB penalty when impulsiveness, tonality, or modulation is distinguishable in the noise, and a recommended setback distance of one kilometer (0.62 miles).[90]

In addition to the report published by the EPHC, the Community Affairs References Committee of the Australian Senate just completed an inquiry involving the general public entitled "The Social and Economic Impact of Rural Wind Farms." [91] Over 1000 people or groups involved in or impacted by wind facility development provided input regarding noise, health, quality of life, setbacks, property values, income, and employment opportunities. Based on the received input, this committee developed seven recommendations for federal, state and territory governments as well as national research groups. The recommendations advocated for new epidemiological research, as well as continued review of published literature, on potential health impacts of wind turbines especially regarding noise and infrasound. The Australian federal government is recommended to consider establishing a national policy of setback distances from wind turbines. States and territories are recommended to verify that wind facilities comply with existing standards, quickly respond to complaints, and develop ways to evaluate the amount of low frequency noise and vibrations at residences. [91]

As this document was just completed, it is not known whether the Australian government will follow these recommendations. The impact of these recommendations may also depend on the release of an updated position on wind facilities and health by the National Health and Medical Research Council, expected in fall 2011.[92] An Australian standard on measuring and assessing noise from wind turbine generators has also been created by a committee with members from the government, research science, and industry. This standard is not required at any level of Australian government, but used as an industry tool for development.[93]

Victoria.

The state of Victoria has developed more protocols regarding wind facility development than the other Australian states.[94] Victorian officials running for election have declared a commitment to create a two kilometer (1.24 mile) turbine setback from all residences. As an election commitment, it may be years before this is put into place, if at all.[94] Victoria recently amended the Victoria Planning Provisions: Wind Energy Facility Provisions, to place more weight on the possible impacts on the local community. This amendment, VC78, requires

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[91] The Senate: Community Affairs References Committee. (2011). The Social and economic impact of rural wind farms. Retrieved from http://www.aph.gov.au/senate/committee/clac_ctte/impact_rural_wind_farms/index.htm

[92] Locker, S. (2011). Health review promised into wind farms. Retrieved from http://www.abc.net.au/rural/content/2011/s3239888.htm

[93] Committee EV-016, Acoustic- Wind Turbine Generator Noise. (2010). Australian Standard: Acoustics-measurement, prediction and assessment of noise from wind turbine generators (AS 4959-2010). Retrieved from http://infostore.saiglobal.com/store2/results2.aspx?keyword=AS4959&Db=AS&searchType=simple&Status=all&publisher=AS&Max=15&Search=Proceed

[94] (Jessica Rabone, personal communication, June 15, 2011).

additional work of applicants for wind facilities, including detailed maps of residence locations within two kilometers (1.24 miles) and noise assessment according to the "New Zealand Standard NZS 6808:2010, Acoustics- Wind Farm Noise."[95, 96] This amendment also transfers the responsibility of permits for wind facilities over 30 MW from the Minister for Planning to local councils.[95]

The New Zealand noise standard referred to in the amendment sets noise limits as the greater of 40 dB $L_{A90,\ 10\ min}$ or 5 dB above the existing background noise, with a more strict limit of 35 dB $L_{A90,\ 10\ min}$ for quieter areas.[96] In addition to the clause amendment, Victoria has also published "Policy and Planning Guidelines for the Development of Wind Energy Facilities in Victoria."[97] This document provides an assessment framework, standards for operation, and the requirements for applying for a wind facility planning permit. It acknowledges concerns relating to the landscape, environment, desirability of living area, quality of life, and heritage, and describes in detail what should go into the planning application to meet the requirements in the planning provisions.[97]

Western Australia.

The Western Australian Planning Commission put out a planning bulletin on "Guidelines for Wind Farm Development."[98] These guidelines focus on matters of wind facility planning and reducing negative impacts on the environment and the community while achieving efficient wind energy development. It contains recommendations to mitigate possible negative effects of the wind turbines. To reduce the visual impact, it recommends burying cables underground, choosing the same design and off-white color for all turbines, using fewer, larger models, diminishing clutter and plant removal, and siting turbines to fit the landscape. To avoid large increases in noise levels, they recommend setbacks based on sound studies, with a guideline of one kilometer (0.62 miles).

While Western Australia does not have specific guidance on wind turbine noise levels for these setbacks, it supports using the guidelines established by South Australia, with a maximum of 35 dB(A) or 5 dB(A) above existing background noise for a 10 minute $L_{A\ eq}$. For other possible human impacts, including, shadow flicker, Western Australia recommends using simulation to achieve correct siting. The guidelines also state that applications for wind facility development should include assessment of possible environmental effects and mitigation strategies.[98]

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[95] Victoria Department of Planning and Community Development (DPCD). (2011). Advisory note 35: Amendment Vc78: Wind energy facility provisions- Clause 52.32. Retrieved from http://www.dpcd.vic.gov.au/_data/assets/pdf_file/0011/59897/AN35-Amendment-VC78-wind-energy-facility-provisions.pdf

[96] [3]Standards New Zealand. (2010). Standards New Zealand factsheet: Revised wind farm noise standard NZS 6808:2010- Frequently asked questions. Retrieved from http://www.standards.co.nz/NR/rdonlyres/93932348-FE1F-44A9-853F-CAOC735A79C0/0'WindFarmNoise_factsheet.pdf

[97] Victoria Department of Planning and Community Development (DPCD). (2011). Policy and planning guidelines for the development of wind energy facilities in Victoria. Retrieved from http://www.dpcd.vic.gov.au/__data/assets/pdf_file/0018/43227/Wind-Energy-Facilities-Guidelines.pdf

[98] Western Australian Planning Commission. (2004). Planning bulletin: Number 67: Guidelines for wind farm development. Retrieved from http://www.planning.wa.gov.au/Plans+and+policies/Publications/210.aspx

South Australia.

South Australia does not appear to have any documents relating specifically to wind facilities except for "Wind Farms Environmental Noise Guidelines."[99] These guidelines by the Environment Protection Authority identify unique features of wind turbine noise, noise measurement techniques, and recommended noise levels at surrounding residences. The $L_{A\ eq,\ 10\ min}$ should not be greater than 35 dB(A) for rural, 40 dB(A) for non-rural areas, or 5 dB(A) above the background noise measured in $L_{A90,\ 10\ min}$. If a specific tone may be heard at a dwelling, the noise level should be ranked as 5 dB(A) higher than the actual sound. These guidelines are used to assist in the determination of wind turbine siting.[99]

Tasmania.

Tasmania has one document relating to wind facility development, a "Noise Measurement Procedures Manual."[100] This document refers to the New Zealand noise standard.[101] It identifies a need for specific wind facility measurement techniques due to higher wind speeds than usual noise measurement situations, and therefore outlines procedures for measuring noise and specific traits including modulation, tonality, and impulsiveness. However, this manual does not outline specific sound limits.[100]

New South Wales.

New South Wales has published a "NSW Wind Energy Handbook."[102] This handbook includes information regarding wind energy, including best practices for developing wind facilities with minimal impact. The handbook suggests that developers consider community acceptance, compatibility, visual, noise, environmental effects, and interference with communication systems when designing a wind facility. For wind facilities over 30 MW, an environmental impact statement must be submitted that justifies the project and identifies potential problems and preventative measures.

An appendix from the handbook deals specifically with mitigating possible impacts from wind facilities. This section states that no set procedure exists for New South Wales for assessing and controlling noise at wind facilities. It states that some builders have used the New Zealand standard and it may be useful, but it does not appear that the government advocates for the use of the standard.[103] This appendix does state that noise specifically from wind turbines cannot usually be differentiated from other sounds when someone is 350 meters (1,148 feet) away.[102]

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[99] South Australia Environment Protection Authority. (2009). Wind farms environmental noise guidelines. Retrieved from http://www.epa.sa.gov.au/xstd_files/Noise/Guideline/windfarms.pdf

[100] Tasmania Department of Primary Industries, Water and Environment: Environment Division. (2004). Noise measurement procedures manual. Retrieved from http://www.environment.tas.gov.au/file.aspx?id=1855

[101] Standards New Zealand. (2010). Standards New Zealand factsheet: Revised wind farm noise standard NZS 6808:2010- Frequently asked questions. Retrieved from http://www.standards.co.nz/NR/rdonlyres/93932348-FE1F-44A9-853F-CAOC735A79C0/0'WindFarmNoise_factsheet.pdf

[102] Sustainable Energy Development Authority (SEDA). (2001). NSW wind energy handbook 2002. Retrieved from http://www.dtiris.nsw.gov.au/_data/assets/pdf_file?0003/306048/nsw-wind-energy-handbook.pdf

[103] Standards New Zealand. (2010). Standards New Zealand factsheet: Revised wind farm noise standard NZS 6808:2010- Frequently asked questions. Retrieved from http://www.standards.co.nz/NR/rdonlyres/93932348-FE1F-44A9-853F-CAOC735A79C0/0'WindFarmNoise_factsheet.pdf

For possible visual impacts, the appendix acknowledges that public reaction to seeing wind turbines is varied, but should be considered. Using identical light-gray or white wind turbines, spacing them to fit the landscape, and same-direction blade rotation help reduce visual impacts. According to this document, shadow flicker is not an issue due to distances to reduce noise levels. This document only provides guidelines for development, and does not identify any specific setback distances, but rather gives an overview of wind energy.[102]

Ireland

Ireland has developed a detailed document called the" Wind Energy Development Guidelines."[104, 105] Among other issues, these planning guidelines discuss possible impacts on historical sites, noise levels, shadow flicker, safety, setbacks, and communication systems. Recommendations pertaining to noise appear to be similar to the noise guidelines used in England, with a 43 dB(A) limit at night and 45 dB(A) limit in the day or 5dB(A) above background noise, with a 35-40 dB(A) $L_{A90,\ 10\ min}$ in quiet rural or residential areas. Noise guidelines should be applied to homes and places such as health, worship, school, and recreational buildings and areas. This document states that noise from wind turbines should not be an issue at distances farther than 500 meters (1,640 feet), which seems to endorse a 500 meter setback. For transportation systems, a setback equal to the height of the turbine is considered a best practice. It is stated that turbines need to be sufficiently removed from power lines and airports, but does not identify a specific distance to ensure safety.

The planning guidelines also address shadow flicker by advising that houses and workplaces within 500 meters (1,640 feet) of a wind turbine should not be exposed to more than 30 hours per year, or 30 minutes per day of shadow flicker. It also mentions that shadow flicker is not an issue for people living more than ten turbine diameters from a wind turbine. It is not clear whether the document recommends a setback distance of 500 meters (1,640 feet) or 10 turbine diameters. Counties are responsible for regulating wind facility development and siting, but must demonstrate use of these guidelines in their own plans. [105]

New Zealand

New Zealand does not have any rules or recommendations for wind turbine setback distances.[106] However, they have created a noise standard" NZS 6808:2010" specifically for wind turbines that is used by several Australian states in addition to New Zealand.[107] This standard stipulates that sound levels outside homes near wind turbines should remain below 40 dB(A) or 5 dB(A) above the background sound level, whichever is greater. If the wind turbines are placed in an environment with few other sources of noise, the noise limit is lowered to the greater of 35 dB(A) or 5 dB(A) above the background sound levels. [107] These noise levels are

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[104] (Una Dixon, personal communication, June 21, 2011).

[105] Department of the Environment, Heritage and Local Government. (n.d.).Wind energy development guidelines. Retrieved from http://www.environ.ie/en/Publications/DevelopmentandHousing/Planning/FileDownLoad,1633,en.pdf

[106] (Ben Farrell, personal communication, August 21, 2011).

[107] Standards New Zealand. (2010). Standards New Zealand factsheet: Revised wind farm noise standard NZS 6808:2010- Frequently asked questions. Retrieved from http://www.standards.co.nz/NR/rdonlyres/93932348-FE1F-44A9-853F-CAOC735A79C0/0'WindFarmNoise_factsheet.pdf

designed to meet the nighttime noise levels recommended by the World Health Organization.[108] Based on scientific studies, these noise limits are believed adequate to avoid any possible effects to health or quality of life.

In New Zealand, local government councils are required to have a local planning document for land development; however, these documents are not required to include wind energy development.[106] One local council has proposed a large setback requirement for wind turbines, but as it is not based on scientific data it is being contested. All wind facilities must secure approval based on a Resource Management Act and be consented to by the Environmental Court before development. The New Zealand Wind Energy Association is currently working on best practices for wind facility development, but this document has not been published as of yet.[106]

Discussion and Conclusion

Very few countries have mandatory wind turbine setback distances between wind turbines and homes. Instead of set wind turbine setback distances, many countries regulate how close wind turbines may be located to residences through noise limits or shadow flicker limits. Some countries have requirements for wind turbine setback distances, noise limits, and shadow flicker limits, while other countries may require noise limits but recommend setback distances. It appears that noise limits are usually requirements, but shadow flicker limits and setback distances are more commonly recommendations. Many countries leave wind turbine noise regulation, setback distance determination, and siting to the states, provinces, or local governments. Most of these countries provide guidelines for their state and local governments, but local governments often create their own regulations or recommendations for wind turbine setback distances instead of or in addition to national recommendations.

In general, wind turbine setback distances appear to be fairly similar across countries and regions. Figure 2 demonstrates wind turbine setback distances in countries or regions that have established required or recommended setback distances from residences. As some countries have different setback distances based on the number of residences, size or number of wind turbines, and other factors, Figure 2 shows the lower and upper setback distance for each area, with the blue bars representing the lowest setback distances, and the blue plus the green bars representing the highest setback distances. Of course, developers may choose to locate their wind turbines farther from homes than the setback distances identified by the governments, as these setbacks are the minimum distance a wind turbine can be placed from a residence.

Generally, the more residences and wind turbines, the greater the required or recommended setback distance. Some countries or regions only had one setback distance rather than a range of distances, as demonstrated by the countries with no green bar in Figure 2. For countries with required or recommended wind turbine setback distances, the average lower setback distance is approximately 470 meters (1,542 feet), and the average upper setback distance is approximately 700 meters (2,297 feet). This is demonstrated in Figure 2, with the majority of setback distances falling between 500 and 1000 meters. The major exception is the

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[108] World Health Organization: Regional Office for Europe. (2011). Noise: Facts and figures. Retrieved from http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/noise/facts-and-figures

upper setback distance for Scotland at 2000 meters (6,561 feet), which is specifically a setback from towns and villages, not individual homes.

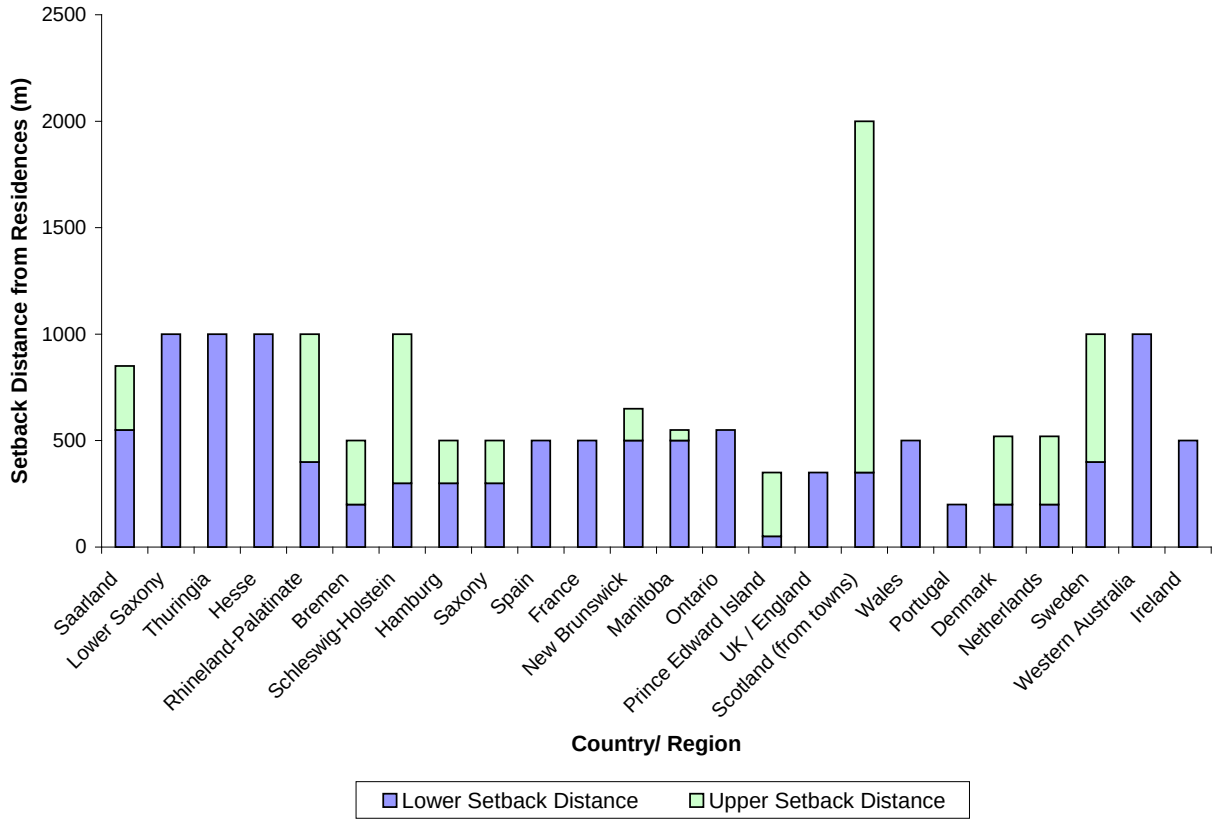

Figure 2: Country Wind Turbine Setback Distances from Residences.

Noise limits for wind turbines are also fairly similar across countries and local regions. Like setback distances, noise limits vary based on the number and size of wind turbines and the number of nearby residences, but are also based on the wind speed and the time of day. Generally, noise limits are lower during the night and in rural areas with few residences, and higher during the day and in areas with a greater amount of residences and pre-existing background sound. In some areas the noise limit increases as the wind speed increases because the natural sound from the wind is amplified along with the noise from wind turbines.

Figure 3 represents the noise limits at residences in countries and regions that have required or recommended noise limits at residences near wind turbines. The blue bars in Figure 3 represent the lower noise limits, and the blue plus green bars represent the upper noise limits at residences near wind turbines. The average lower noise limit is approximately 35 dB(A), and the average upper noise limit is 45 dB(A). This is demonstrated in Figure 3, with most noise limits between 30 and 50 dB(A), and all noise limits between 25 and 65 dB(A). A major outlier is the French noise limit of 25 dB(A), but this is for inside residences rather for outside them like the rest of the noise limits. As with setback distances, wind energy developers may choose to enforce stricter noise limits than the government but are under no obligation to do so.

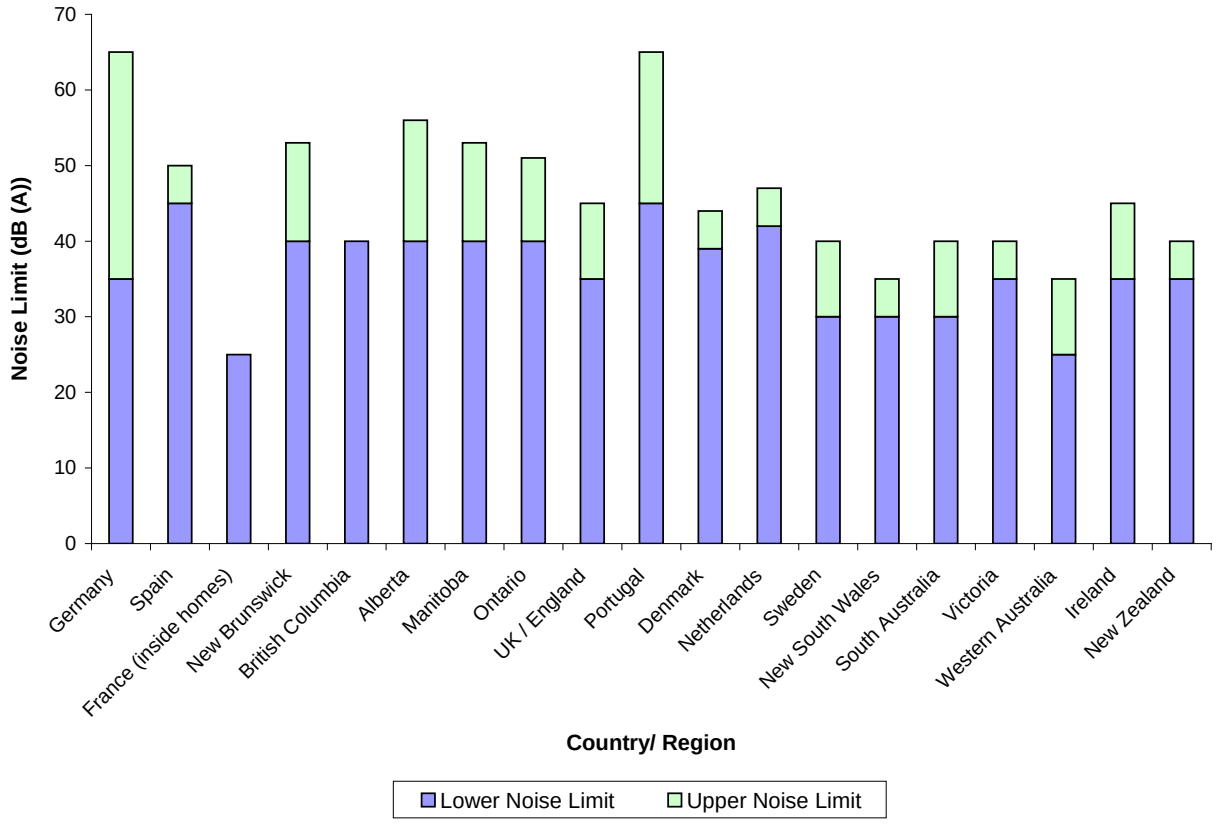

Figure 3: Country Wind Turbine Noise Limits at Residences

There were several other factors mentioned by national and local governments that were taken into consideration in wind energy development. Shadow flicker was most often mentioned, with several countries requiring or recommending a shadow flicker exposure limit of 30 hours per year in a worst case scenario. Germany has done the most work in this area, and countries that focus on shadow flicker usually refer back to Germany's standards, even though many countries do not appear to have much knowledge of actual policies in Germany. Other countries mention that shadow flicker exposure should be investigated, but provide no indication of acceptable levels of shadow flicker.

Besides shadow flicker, the visual impact of the wind turbines seems to be the factor most often mentioned for wind energy developments. The visual impact of wind turbines seems to be a concern, especially in areas with beautiful landscapes. While this is a concern, there do not seem to be any policies or recommendations specifically related to visual impact but instead the visual impact is sometimes used as a rationale for setback distances from residences.

Other concerns mentioned by governments included consideration for resident's preferences and safety concerns. The potential for ice or a blade to be thrown from a turbine were the main safety concerns, but setback distances and noise limit requirements usually made turbines far enough away from residences to be safe, so few countries found it necessary to create recommendations for safe distances from wind turbines. Overall, noise limits and setback distances were the most widely used means of regulating wind turbine siting and placement, and a majority of countries used wind energy siting recommendations rather than regulations.

Countries with more developed and clear wind energy policies generally have more wind energy and less opposition from those living near wind energy facilities than countries with few requirements or guidelines. For example, Denmark has a well-developed booklet clearly stating all of the policies and recommendations regarding wind energy. Denmark also has the largest amount of wind energy per capita and per land area, and little opposition is seen in online websites or comments. Australia, on the other hand, does not have a national policy or recommendations. Although Australia is one of the fifteen top wind energy producers in the world, their actual amount of wind energy is very small compared to the potential based on land features. Australia also just had to complete an inquiry of the general public's opinions of wind energy, and they found many people had negative perceptions of wind energy. It appears that developing clear, direct policies or recommendations for wind energy increases the acceptance of wind energy by the general population and thus increases the overall amount of wind energy in a country or area.

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Appendix A

Basic Email Transcript

To whom it may concern:

My name is Kathryn Haugen and I work for the Minnesota Department of Commerce in the United States. During our application process for large wind farm development, many members of our public have presented information regarding the setback distances set forth by various countries between wind turbines and residential homes. As we understand that this information contains both accurate and inaccurate data, I am working to compile correct information on wind farm requirements in other countries.

Some of my questions include:

Does *(Country Name)* have any *required or recommended* minimal distance or standards for separating wind turbines (for large systems) from residences? Are there any documents that give examples of these?
If there are rules or guidelines, why were they created (noise levels, shadow flicker, landscape, housing values, other concerns)?
If there are rules or guidelines, are they primarily based on scientific research or public opinion?
If *(Country Name)* does not have any rules or guidelines, what other controls exist regarding setback distances between wind turbines and residences?
Thank you so much for your time. Any input you are able to provide is very helpful.

Sincerely,

Kathryn Haugen

Appendix B

List of Contacts

Name	Country/Area Provided Information for:	Organization/Position
Nicola Saccà	Saarland, Germany	Leiter des Referats B/1 - Klimaschutz, Energiepolitik, Erneuerbare Energien
Dania Röpke	Germany	Referentin Politik / Policy Advisor Bundesverband WindEnergie/ German WindEnergy Association
Christoph Brand	Germany	
Johannes Pohl	Germany	Lead Researcher on Shadow Flicker Studies
Daniela Degen-Rosenberg	Germany	Rechtsanwältin/Justitiarin wpd onshore GmbH & Co. KG
Rainer Mausfeld	Germany	Researcher on Shadow Flicker Studies
Lars Bobzien	Lower Saxony, Germany	Niedersächsisches Ministerium für Umwelt und Klimaschutz Referat 10 - Energiepolitik, Klimaschutz, Klimafolgen, Nachhaltigkeit
Dirk Otto	Thuringia, Germany	Unit for Renewable Energies Thuringian Ministry for Economy, Labour and Technology
Klaus Gütling	Hesse, Germany	Hessisches Ministerium für Umwelt, Energie, Landwirtschaft und Verbraucherschutz Referat VIII 3 "Energietechnologien, Netzintegration der erneuerbaren Energien"
Kai Demske	Bremen, Germany	Freie Hansestadt Bremen Der Senator für Umwelt, Bau und Verkehr
Ulrich Gallent	Rheinland-Pfalz, Germany	Sachbearbeiter, Dipl.-Ing. (FH) Energietechnik, Energieeffizienz, Erneuerbare Energien

		Berichtswesen, Kompetenznetzwerke, Klimawandel Ministerium fur Wirtschaft, Klimaschutz, Energie und Landesplanung Rheinland-Pfalz
Günther Sauer	Berlin, Germany	Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz
Juan Ramón Ayuso Ortiz	Spain	Wind Energy Department IDAE - Instituto para la Diversificación y Ahorro de la Energía Ministerio de Industria Turismo y Comercio
Tomás Cambreleng Lundager	Spain	Técnico de Proyectos Departamento de Energías Renovables: División de Investigación y Desarrollo Tecnológico
Karina Lindvig	Denmark	Advisor Danish Wind Industry Association
Denis Zborowski	Ontario, Canada	Program Manager/Chef de programme Renewable Power/Électricité renouvelable Natural Resources Canada/Ressources naturelles Canada
Rick Halas	Manitoba, Canada	IEM
Ian McKay	Alberta, Canada	Executive Director Infrastructure and Alternative Energy Electricity, Alternative Energy, and Carbon Capture and Storage
Mathieu Roy	Quebec, Canada	M. ATDR Direction du développement des énergies renouvelables Direction générale de l'électricité Ministère des Ressources naturelles et de la Faune
Sean MacKinnon	Yukon, Canada	Senior Energy Advisor Energy Solutions Centre Dept. of Energy Mines & Resources Yukon Government

Susan Bragoli	United Kingdom, Scotland, Wales	government
Marlene Oliveira das Neves	Portugal	government
Agostinho Miguel	Portugal	Energias Renováveis
Pia Jensen	Denmark	Cand polit Ministry of Climate and Energy Danish Energy Agency
Albert Jansen	The Netherlands	Senior Programma Adviseur NL Energie en Klimaat Agentschap NL
Eva Centeno-Lopez	Sweden	Departementssekreterare Näringsdepartementet Energienheten Head of Section Ministry of Enterprise, Energy and Communications Division for Energy
Bengt Larsén	Sweden	Vindlov- Boverket – Myndigheten för samhällsplanering, byggande och boende National Board of Housing, Building and Planning
Jessica Rabone	Australia	Senior Policy Officer, Renewable Energy Policy Department of Resources, Energy and Tourism
Una Dixon	Ireland	Planning and Development Section Dept of Environment Heritage & Local Government Custom House
Ben Farrell	New Zealand	Senior Environmental Planner & Project Manager Guidelines New Zealand Wind Energy Association
Amanda Baudry	France	Responsable Communication EOLE-RES
Amy Berry	Organization	RES Americas
Åsa Jönegren	Organization, suggested contacts	Projektledare / Development Project Manager Nordisk Vindkraft
Citizen Information Service in Energy Efificency and Renewable Energies (SICER)	Spain	Citizen Information Service in Energy Efificency and Renewable Energies (SICER)

Jan Rullens	The Netherlands	Voorlichter Antwoord voor bedrijven
Inquiry, Centre ENV	Saskatchewan, Canada	Inquiry, Centre ENV
Helen Kwan	Ontario, Canada	Senior Project Advisor Renewable Energy Facilitation Office Ministry of Energy
Paul Dmytruk	Alberta, Canada	Rates Division, Specialist Alberta Utilities Commission
Paul Gipe	Specialist, Suggested Contacts	GC
Stewart Bengert	Saskatchewan, Canada	P.Eng. Supply Development, SaskPower
Agecam	Castilla-La Mancha , Spain	Energy Telephone Service of the Regional Energy Agency of Castilla-La Mancha
Geoff Turner	British Columbia, Canada	government
Rose Brewster	Saskatchewan, Canada	Webmaster ER
Franz Faul	Germany	Researcher on Shadow Flicker Studies, forwarded email
Salvador Suárez García	Spain	Jefe del Departamento de Energías Renovables División de Investigación y Desarrollo Tecnológico, Forwarded email

Appendix C

Wind Energy Terms

Note: Wind energy terms are not always used in the same way across various countries or sources. These definitions are based on how terms appeared to be most commonly used throughout countries and sources in this document.[109, 110]

Wind Energy: The provision of energy from wind, usually harnessed through wind turbines.
Wind Energy Requirement, Rule, Law, or Policy: A wind energy setback or limit required by a level of government.
Wind Energy Recommendation or Guideline: A wind energy setback or limit that is suggested or encouraged, but not required, by a level of government.
Wind Turbine: A system used to convert potential energy found in wind to mechanical energy to produce electricity. Wind turbines usually range in size from 9 to 200 meters (29- 427 feet), and may be located onshore or offshore.
Onshore Wind Turbine: A wind turbine that is located on land. Onshore wind turbines may range in size from small wind turbines producing 50 kilowatts of electricity a day, to large wind turbines producing up to 3 megawatts of electricity a day.
Offshore Wind Turbine: A wind turbine that is located in deep water such as seas or oceans. Offshore wind turbines are much larger than onshore wind turbines, producing up to 6 megawatts of electricity a day.

Vertical-Axis Wind Turbine: A wind turbine where the blades rotate around an axis that is perpendicular to the ground. Vertical-axis wind turbines are often described as resembling egg-beaters.
Horizontal-Axis Wind Turbine: A wind turbine where the blades rotate around an axis that is parallel to the ground. Horizontal-axis wind turbines are more common that vertical-axis turbines, and usually contain three blades.
Wind Energy Facility, Wind Power Plant, or Wind Farm: A group of three or more wind turbines operated together. A wind energy facility may include several hundred turbines.
Tower: The tall base that serves to raise and anchor the wind turbine blades.
Hub: The area the blades rotate around in a horizontal-axis turbine. The hub is parallel to the ground and contains the mechanical pieces including a gearbox and generator.
Blades: The sections of the wind turbine that the wind moves. There are typically three blades which rotate around the hub.
Turbine Height: The height from the ground to the top of the turbine. In a horizontal-axis turbine, it is the height from the ground to the top of the highest rotating blade.

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[109] U.S. Department of Energy: Energy Efficiency & Renewable Energy. (2011). Energy basics: Glossary of energy related terms. Retrieved from http://www.eere.energy.gov/basics/glossary.html#W
[110] Environment Protection and Heritage Council (EPHC). (2010). National wind farm development guidelines: Draft July 2010. Retrieved from http://www.ephc.gov.au/node/449

Hub Height: The height from the ground to the center of the hub the blades rotate around on a horizontal-axis wind turbine.
Rotor Diameter: The diameter of the circular arc produced by the rotation of the blades. **Wind Turbine Mean Power Output:** The average amount of energy produced by a wind turbine or wind energy facility over a given period of time for an average wind speed, usually measured in megawatts or kilowatts.
Megawatts (MW): One million watts, or one thousand kilowatts of energy.
Kilowatts (kW): One thousands watts of energy.
Watts (W): The amount of energy used or produced by an object.
Mean Wind Speed or Velocity: The average rate over a period of time of the flow of wind with no blocking obstacles such as buildings or vegetation.
Setback: The minimum distance a wind turbine may be located from a designated location. Unless otherwise specified, setbacks refer to the minimum distance a wind turbine may be located from a residence. The term setback is also used to describe minimum distances from all buildings, property lines, or historically or environmentally important areas. Setbacks may be a set distance or based on turbine features including turbine height, hub height, rotor diameter, or blade length. Setbacks may also be referred to as a setback distance or separation distance.
Shadow Flicker: The pattern of alternating shadows and light caused by the changes in light when rotating blades cast shadows on an area or residence. Shadow flicker only happens when the sun is low in the sky and behind the rotating turbine blades.
Shadow Flicker Exposure: The amount of time a location experiences shadow flicker, measured in terms of the actual or the “worst-case” scenario.
Shadow Flicker Standard or Shadow Flicker Limit: The maximum exposure to shadow flicker allowed at residences near wind turbines.
Disco Effect: Repeated flashes of light produced by the sun reflecting off rotating blades. This term has only been widely used in Germany, but is often confused with shadow flicker.

Appendix D

Noise Terms[111, 112]

Sound: Vibrations conveyed through the air that may be heard.
Noise: Unwanted sound.
Noise Standard or Noise Limit: The maximum volume from wind turbines allowed in an environment. The noise limit may vary based on the time of day, size and number of turbines, and number of nearby residences or educational or work settings. Usually, the noise limit refers to the volume at nearby residences.
Background Noise: Sounds present in the environment on a regular basis. In terms of wind energy, usually refers to the sounds present before wind turbines are installed.
Residence, Dwelling, or Home: A place where people live.
Residential Area: An area with a number of residences, or an area where residences are the main features instead of commercial, service, industrial, or agricultural facilities.
Quiet Area: An area, usually residential or rural, with little existing background noise.
Wind Facility Neighbor or Receiver: Residences or businesses near to wind facilities, often close enough to call for measurement of sound or shadow flicker levels.
Decibel (dB): The unit used to measure the volume or intensity of a sound.
A-weighting or dB(A): A standard measure of sound volume that is widely used internationally, with sounds weighted more or less depending on their frequency. dB(A) is designed to measure how loud sounds appear to the normal human ear and generally weights sounds with higher frequency levels as appearing louder than lower frequency sounds.
C-weighting or dB(C): A standard measure of sound volume, with sounds weighted more or less depending on their frequency. dB(C) uses less weighting than dB(A) for especially lower frequency sounds, which are rated louder in dB(C) than in dB(A). C-weighting is less widely used than dB(A), but is used when there is concern about the amount of lower frequency sounds from equipment or power sources.
Frequency: The number of oscillations per second of sound waves, measured in Hertz (Hz). Humans can normally hear sounds with frequencies ranging from 20-20,000 Hz.
Infrasound: Sounds at frequencies below 20 Hz that humans cannot hear.
Low Frequency Sound: Sounds at frequencies from 20-200 Hz that humans can usually hear.
Modulation: Regular, audible fluctuations in the sound volume.
Tonality: A sound at a specific, discrete frequency rather than a range of frequencies that produces a distinct tone, like a hum.
Impulsiveness: A repeated short sound, such as banging.
Sound Pressure: The difference in the local air pressure caused by a sound wave.

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[111] U.S. Department of Energy: Energy Efficiency & Renewable Energy. (2011). Energy basics: Glossary of energy related terms. Retrieved from http://www.eere.energy.gov/basics/glossary.html#W

[112] Environment Protection and Heritage Council (EPHC). (2010). National wind farm development guidelines: Draft July 2010. Retrieved from http://www.ephc.gov.au/node/449

Sound Pressure Level (SPL): The measure of the sound pressure, or the difference in the local air pressure caused by a sound wave, relative to a standardized value at a distance from a source of a sound.

$L_{A90,\ 10\ min}$ or L_{A90}: The sound pressure level in dB(A) that is equaled or exceeded for 90% of the time measured, often a 10 minute interval.

$L_{A95,\ 10\ min}$ or L_{A95}: The sound pressure level in dB(A) that is equaled or exceeded for 95% of the time measured, often a 10 minute interval.

$L_{A\ eq,\ 10\ min,}$ $L_{A\ eq}$ or L_{eq}: The average sound level over a period of time in dB(A), or the continuous sound level that would equal the average of multiple sound pressure levels for a fluctuating sound.

$L_{A\ max,\ 10\ min}$ or $L_{A\ max}$: The highest sound pressure level I dB(A) that occurs within the time measured, often a 10 minute interval.