Superior Health Council

PUBLICATION OF THE SUPERIOR HEALTH COUNCIL No. 8738

Public health effects of siting and operating onshore wind turbines

In this scientific policy advisory report the Superior Health Council of Belgium answers questions on the impact on health and well-being of siting wind farms in residential areas, placed in a context of sustainable development.
The Superior Health Council formulates general recommendations as well as recommendations linked to specific physical environmental factors in order to develop onshore wind energy in a socially acceptable way, taking a quality of life perspective.

3 april 2013

SUMMARY

In this advisory report, the Superior Health Council (SHC) provides an answer to questions that were submitted by the President of the Federal Public Service Health, Food Chain Safety and Environment on the health effects of siting wind farms in populated areas. The answers are put in a quality of life context with a view to promoting sustainable development, taking into account a subsequent request of the Federal Minister of Social Affairs and Public Health.

Based on a review of the scientific literature and additional publications, the conclusions of the Council are as follows:

Modern wind turbines are unlikely to have any direct effects on health and well-being other than annoyance and possibly sleep disturbance. Both annoyance and disturbed sleep can, however, lead to undue stress, which may adversely affect the health and well-being of those concerned.

If the notion of "health" is extended to that of the quality of life, or if it is also taken to include "well-being", a main environmental health effect is the annoyance that people attribute to the noise of the operating wind turbines, both when awake and asleep. The level of annoyance — both individually and among the population — can only be understood by taking into account other factors, such as the way in which the wind turbines or wind farms change the landscape, intrude on people's attachment to the local environment, as well as the question whether the wind turbine project generates any benefits or costs for the local economy. The way in which the (future) quality of life is perceived as a result determines whether the wind turbine project will achieve social acceptance from the local community. However, if the quality of life is felt to deteriorate (or if it is feared that it will do so in the future), this may generate or worsen health complaints in some people, who will e.g. feel depressed, suffer from headaches or hypertension.

It follows that the operation of wind turbines or wind farms may affect the quality of life (i.e. health and well-being), but in a complex fashion that depends on a variety of interrelated factors. There is no simple, universally valid connection with a single, specific environmental factor such as, e.g., the exposure to wind turbine noise or the changed appearance of the landscape. Nevertheless,

diminishing noise exposure or taking landscape features into account in designing wind turbine projects may improve the quality of life, or reduce its deterioration.

The Council issues the following eight recommendations on developing onshore wind energy in a socially acceptable way. In doing so, it focuses on how to safeguard the quality of life (i.e. health and well-being).

1 Perform a life cycle analysis of the various options that are available in Belgium to generate electricity. This analysis should attempt to express their public health impacts both in monetary terms and by using measures of population health such as disability adjusted life years. It should also take into account the distributional effects of the benefits and adverse health effects of these different options. Such a study should include an estimate of the Belgian at-risk population.

2 The noise levels due to the operation of wind turbines and wind farms near people's homes should comply with the World Health Organisation (WHO) and WHO Europe guidelines for day-time and night-time noise exposure in order to avoid serious annoyance and (self-reported) sleep disturbance. This would lead to sound levels below 45 dB(A) during day-time and 40 dB(A) at night. If such values are already exceeded by other noise sources, the wind turbine noise contribution might be limited to an unnoticeable increase in noise level, depending on the masking potential of the existing noise levels.

3 Effects from the shadow flicker caused by the operating wind turbines should be avoided by carefully selecting the location and design of wind turbine projects. If shadow flicker cannot be avoided, the Council advises to comply with the North Rhine-Westphalia standard for shadow flicker, i.e. 30 h per year and 30 minutes per day, regardless of cloud cover.

4 Safety issues related to wind turbine operation should be taken seriously but can be resolved by means of appropriate measures. These measures include quality control during construction and operation (structural failure), location selection (structural failure and aviation and traffic safety), infrastructure measures (structural failure and traffic safety) and technical measures (aviation safety, ice shedding).

5 The design and implementation of wind energy projects should be part of a participatory process in which the stakeholders have a real say in the design, the implementation and operation of the project. For such decisions to achieve social acceptance, it is of paramount importance that the outcome of these processes is not settled beforehand. Rather, the stakeholders should have the opportunity of giving their "green light" to the project, request alterations in its design and operation or suggest that the proposed project be abolished.

6 Local general practitioners should be provided with up to date information about the impacts of wind turbine operation on health and well-being and take part in the participatory design and implementation process.

7 The health status of the population in the vicinity of wind energy projects should be monitored by means of appropriate methods.

8 Belgium should participate in or take the initiative for an international study on the possible specific impacts of wind turbine operation on the health and well-being of those living in their vicinity.

Keywords

Keywords	Mesh terms*	Sleutelwoorden	Mots clés	Stichwörter
Annoyance	-	Hinder	Nuisance	Belästigung
Infrasound	Infra ”sound”	Infrageluid	Infrason	Infraschall
Low frequency sound	Low frequency “sound”	Laagfrequent geluid	Son à basses fréquences	Niedriegfrequenz ton
Noise exposure	“Noise” exposure	Lawaaiblootstelling	Exposition au bruit	Lärmbelastung
Onshore wind turbines	Onshore “wind” turbines	Windturbines op land	Eolienne sur terre	Windenergieanlage auf dem Land
Residential area	Residential “area”	Woonlocaties	Zones habitées	Wohngebiet
Quality of life	“Quality of life”	Levenskwaliteit	Qualité de vie	Lebensqualität
Risk assessment	"Risk assessment"	Risicoanalyse	Evaluation des risques	Risikobewertung
Shadow flicker	-	Slagschaduw	Ombre stroboscopique	Schattenwurf
Sleep disturbance	“Sleep deprivation”	Slaapverstoring	Trouble du sommeil	Schlafstörung
Social acceptance	“Acceptance, social”	Sociale aanvaarding	Acceptation sociale	Gesellschaftliche Akzeptanz
Sound	“Sound”	Geluid	Son	Schall
Sustainable development	“Sustainable development”	Duurzame ontwikkeling	Development durable	Nachhaltige Entwicklung
Vibrations	“Vibration”	Trillingen	Vibrations	Vibration
Landscape	“Landscape”	Landschap	Paysage	Landschaft

** MeSH (Medical Subject Headings) is the NLM controlled vocabulary thesaurus used for indexing articles for PubMed.*

Contents

ABBREVIATIONS AND SYMBOLS

DALY	Disability Adjusted Life Year
SHC	Superior Health Council
WHO	World Health Organization

Units

dB	decibel (sound). The sound level or sound pressure level is defined as 20 times the 10-logarithm of the ratio of the sound pressure and a reference sound pressure (20 micropascal). The resulting values are usually appended by ‘dB’ (decibel) to denote the logarithmic nature of the quantity.
dB(A)	denotes an A-weighted sound level
Hz	hertz, unit of frequency (1 Hz = 1 s-1 or 1 per second)
kHz	kilohertz, 1 thousand (10^3) hertz
L_{den}	The noise exposure metric which represents the daily outdoor noise exposure over a year and takes into account that evening noise is considered more annoying than daytime noise and night-time noise more annoying than evening noise.
L_{night}	The noise exposure metric which represents the outdoor noise exposure over a year during night hours (23-07 h).
W	watt, unit of power
MW	megawatt, 1 million (10^6) watt
GW	gigawatt, 1 billion (10^9) watt

1 INTRODUCTION AND ISSUES

1.1 Wind energy and health

Wind energy is advocated as one of the options to derive electricity from renewable sources (EU 2009). In sea-bordering countries wind turbines and wind farms are constructed both onshore and offshore (Kaldellis and Kapsali 2012). Onshore installations may affect the local environment and have raised concerns about health threats and negative impacts on the quality of life of local residents.

1.1.1 Request for advice

In a letter of March 15, 2011, the President of the Federal Public Service Health, Food Chain Safety and Environment asked the SHC to advise him on the health effects of siting wind farms in populated areas. He mentioned that such wind farms will affect the health and well-being of the population, and referred to the increasing size and electricity generating capacity of modern wind turbines and to public concerns. The questions posed are:

- What are the health risks of the siting of wind turbines and wind farms for people living in the neighbourhood?

- What are the recommendations of the SHC to safeguard well-being and health?

Subsequently the Minister of Social Affairs and Public Health, by letter of May 14, 2012, asked the Council to consider the earlier request in a wider perspective, taking into account concerns about the narrow scope of the original request that were voiced by representatives of the wind energy sector.[1]

1.1.2 Procedure

To prepare a response the Board of the SHC convened a working party of experts that is listed in Chapter 6. The working party consulted publications in international scientific journals, scientific reviews and conference documents, as well as other publications in the general literature. Several of these publications were prepared by expert panels or consultants as part of procedures related to the siting of wind farms. The conclusions and recommendations in the present report are based on the interpretation of the experts convened by the SHC of the available evidence.

The Superior Health Council invited stakeholders to provide evidence on the issue of the present report and to suggest topics that should be discussed (see Chapter 5).

A draft of the present report has been reviewed by two foreign experts (Chapter 6). The Council has taken their comments into account in finalizing the report's text.

[1] Letter of May 2, 2012, of Edora, Fédération des énergies renouvelables, and letter of April 11, 2012, of ODE, Organisatie Duurzame Energie, and VWEA, Vlaamse WindEnergie Associatie, to Minister Onkelinx of Social Affairs and Public Health.

1.1.3 Report

Wind turbines

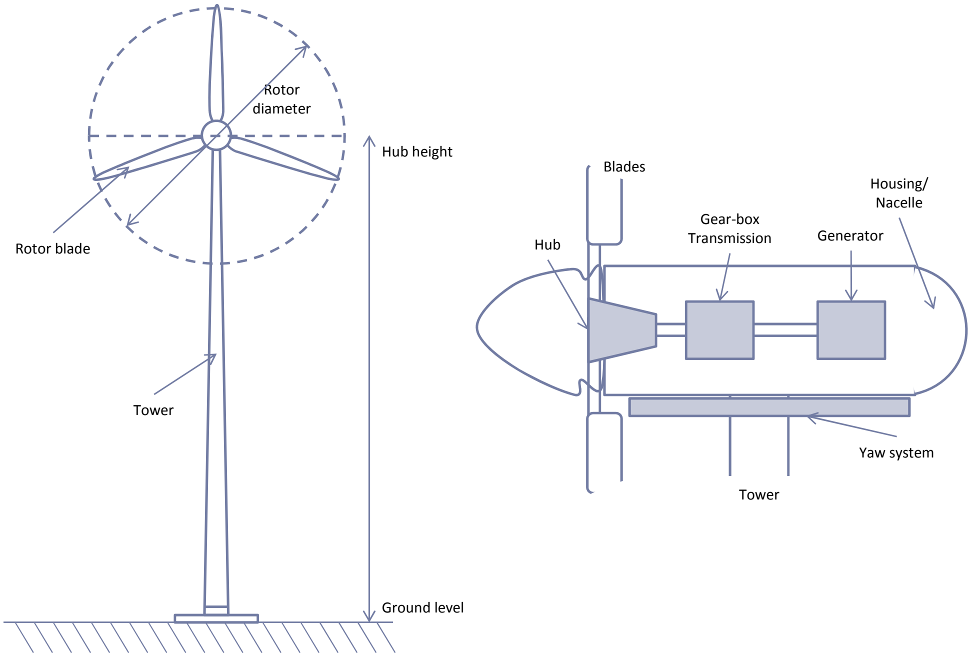

Figure 1 Schematic of a modern wind turbine.

The most common type of a modern *wind turbine* has an upwind rotor with three blades and a horizontal axis (Manwell *et al* 2009) (see Figure 1). A yaw system rotates the nacelle, hub and blades to keep the rotor in an upwind position (facing the incoming wind). The rotational energy of the rotor is transformed into electrical energy in the generator and then further transported to the electricity grid. In this a *wind turbine* differs from a *windmill* that transfers rotational energy into mechanical energy. In the last decades wind turbines have grown in size and power. Present day wind turbines can reach hub heights of 100 m and more with blade lengths of 50 m and more. The maximum electrical power or capacity of a modern wind turbine is in the range of 1 to 10 MW[2] (European Wind Energy Association 2009). Turbines are expected to increase in size and power in the coming years (European Wind Energy Association 2009). A *wind farm* is a group of wind turbines at one site.

Focus

In answering the questions posed, the SHC will only consider onshore wind turbines and wind farms. The wind turbines taken into account are those of present day technology: a three blade, upwind rotor, an insulated nacelle with or without a gear box between rotor and generator and an electrical power in the range of 1 to 10 MW. In this report ‘wind turbines’ may denote individual, separate wind turbines as well as a collection of wind turbines in a wind farm.

The impacts of the construction phase will be mentioned, but the focus is on the impacts on the health and well-being of neighbouring residents during the operational phase. The changes in public health effects related to a switch from traditional energy sources to wind energy for electricity generation are not dealt with in detail, nor are the economics of wind energy as compared to other energy sources. However, the SHC places its report in a context of

[2] MW: megawatt, 1 million (10^6) watt

sustainable development, i.e. policies that strive *inter alia* to safeguard and foster the health and well-being of the present and future generations.

2 FURTHER DETAILS AND ARGUMENTATION

2.1 Wind energy

2.1.1 Sustainable development, climate change and energy policy

The world faces problems related to population growth, diminishing resources and social disparities. Already a quarter of a century ago, a sustainable development road was proposed to tackle these issues (World Commission on Environment and Development 1987). Notwithstanding progress in this direction, these issues are still largely unsolved. Without further policy measures the health and well-being, i.e. the quality of life, of future generations will be affected by global phenomena such as climate change, water scarcity, changes in land use and biodiversity loss (Corvalan *et al* 2005, Huynen *et al* 2008).

These problems are for an important part related to the energy needs of our society (Petford 2012). Nowadays these needs are largely satisfied using finite fuels such as coal, oil, gas, and nuclear. However, international and national policies all strive to diminish our dependence on these energy sources in favour of more sustainable resources. Often these renewable energy sources increase the use of electricity as an energy carrier (in Belgium in 2011 electricity accounted for 17 % of the final energy consumption (ABB 2011)). Even in optimistic scenario's the dependence on traditional fuels will remain great due to the expected population increase and economic growth in particular of developing parts of our world (OECD 2012).

In its 'Roadmap 2050' the European Commission pictures a strong increase in the relative contribution of renewable energy sources, a decrease in that of fossil fuels and a more or less stable relative contribution of nuclear energy for the coming decades (European Commission 2011). Renewable sources are biofuels, sun, wind and ocean waves among others. This outlook is in line with Belgian energy policy documents (Minister van Klimaat en Energie 2008, ENOVER-CONCERE 2010).

Thus, European and Belgian policies clearly strive for a switch to renewable energy sources, and wind energy is to play an important role in this respect.

2.1.2 Energy production and health

Each form of energy generation and consumption has societal impacts among which impacts on health and well-being. These impacts can be both beneficial and harmful. The beneficial health impacts are generally related to the use of the energy.[3] The harmful effects are generally related to physical and chemical environmental impacts in all production phases both from 'normal' operation and from accidents. The latter impacts are largely borne either by society at large or by local communities and are called externalities by economists. From a public health point of view there is a preference using a technology with little or no negative health impacts per unit of energy produced.

Various studies have tried to calculate, usually in monetary terms, the costs and benefits, including the health costs and benefits, of energy production technologies. In Europe the ExternE methodology was developed for quantifying the costs of health and environmental impacts in monetary terms (ExternE 2005, Rabl and Spadaro 2006). Recently these techniques were applied to compare the external costs of various energy scenarios in Flanders (Nijs *et al* 2011).

---

[3] The use can also be detrimental. E.g. the availability of energy for transport has also lead to a lack of exercise.

When comparing electricity production from wind energy with thermal energy production from fossil fuels, health and environmental benefits are obtained by avoiding air pollution, carbon dioxide emissions contributing to climate change and by the reduced use of cooling water (D'Souza *et al* 2011, Kaldellis and Kapsali 2012). This also means that the calculated external costs of wind energy are low compared with other energy technologies, such as coal and nuclear (Nijs *et al* 2011). The external costs for wind energy are for a large part related to the construction and dismantling phase (D'Souza *et al* 2011, Nijs *et al* 2011). The SHC stresses that these calculations inevitably include uncertainties, some of which may be considerable (ExternE 2005, Davidsson *et al* 2012). In interpreting the outcome of external costs calculations these uncertainties have to be taken into account (Stirling 1997, Stirling and Mayer 2000). Furthermore, these approaches imply some degree of aggregation. E.g. all health impacts are usually taken together, but they may pertain to different populations for the different phases of the energy production process. In addition, the distributions of possible benefits and of possible harm of a given technology usually differ. Likewise, different production technologies have impact on different populations, making their comparison difficult on the scale of a region or community.[4]

Apart from monetizing health impacts, other measures have been proposed to quantify health impacts (or quality of life impacts). For environmental health impacts the burden of disease expressed in 'disability adjusted life years' (DALY) has become popular, in any case in Europe (de Hollander and Lebret 1994, Murray and Acharya 1997, de Hollander *et al* 1999, Torfs 2003, Gezondheidsraad 2007). Outcomes in DALYs do differ from those in euros as there is no one to one relationship between both measures (Torfs 2003, de Hollander 2004).[5]

In order to assess the health impacts, both positive and negative, of wind energy for Belgium and comparing those with other energy options, an extensive study would be required. Such a study is outside the scope of the present report. However, the SHC is of the opinion that such a study is useful to underpin energy policies from a public health point of view.

2.1.3 Wind energy in Belgium

In the last decade the generation of electricity in Belgium by wind energy has been on the rise, reaching a capacity of 1 GW[6] today (see Figure 2) (The Wind Power 2012). It is expected that in 2020 the installed capacity will rise to about 4 GW and that wind energy will cover 10 % of the total electricity demand (ENOVER-CONCERE 2010) (or about 2 % of the total energy consumed). Part of the wind turbines with a combined capacity of 0.4 GW (2012) are located offshore in the Belgian part of the North Sea.

---

[4] With some energy technologies, e.g. nuclear, accidents can have important public health impacts. In the methodologies mentioned such impacts are generally not taken into account in the case of very low probability accidents. However, in comparing energy technologies such impacts should be taken into account.

[5] The reason is that in a monetary evaluation the costs are usually computed in an integral way (i.e. for the total health effects), whereas in burden of disease assessments health effects are weighted separately before aggregation.

[6] GW: gigawatt, 1 billion (10^9) watt

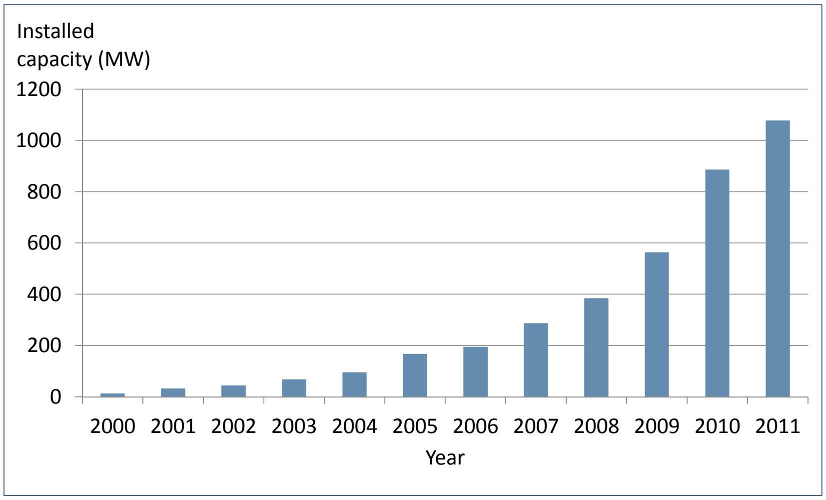

Figure 2 Installed wind energy capacity in Belgium at the end of each year. From (The Wind Power, 2012).

Wind energy policy for onshore installations is the competence of the Belgian regions, whereas the federal government is responsible for offshore installations (ENOVER-CONCERE 2010). The regional governments have pledged to stimulate wind energy in the coming years (Vlaams Minister van Energie 2009, ENOVER-CONCERE 2010, Gouvernement Wallon 2011). Surveys indicate popular support for these policies (European Commission 2006, Ipsos 2010, Van Hamme and Loix 2011), although the common interpretation of these results as a general positive attitude of the population vis-à-vis wind energy has been challenged (Aitken 2010a).

2.1.4 Wind turbine projects and their impact on health and well-being

Even though 'green' energy in general and wind energy in particular appears to be positively viewed by the population in Europe and elsewhere (European Commission 2006), Belgium included (Ipsos 2010, Van Hamme and Loix 2011), siting of wind turbines and in particular of wind farms engenders protests of neighbouring residents (Devine-Wright 2005, van der Horst 2007, Pasqualetti 2011). Also in Belgium plans for erecting wind turbines have generated protests. Examples are the Volvo Trucks factory in Ghent (Herregodts 2008a, b), Willemsvaart in Lanaken near the Dutch frontier (Het Nieuwsblad 2011) and Gembloux (Pacco 2012).

Why do these controversies arise, given the expected benefits of wind energy? Within the context of this report, the SHC cannot explore the possible answers to this question in detail. However, as will be described in the following chapter, many of the issues raised in debates about the implementation of a wind energy project are related to impacts or expected impacts on quality of life. These impacts are not necessarily negative and may be perceived differently by different people. An example of the latter is presented in an essay about visual quality of the environment of an (off shore) wind farm (Good 2006).

Quality of life is a concept that has been defined in a variety of ways, even when related to environmental quality (van Kamp *et al* 2003). The WHO description as the 'individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns is relevant for the discussion in the present report (WHO 1995). The relationship between quality of life aspects and physiological health effects or listed diseases is a complex one and not unidirectional (van Kamp *et al* 2003, van Kamp 2012). Whether ill health is (partly) the result of a reduced quality of life or whether a diminished quality of life (partly) is the consequence of ill health is not known.

Notwithstanding this, the SHC will place its findings on the impact of wind energy on the health of local communities in a quality of life context. Apart from the fact that this is the only basis for a coherent discussion of the health effects that were referred in the (original) request for advice, it has the further advantage that it might provide handles for policymakers in designing decision processes about wind energy projects. In the next section the SHC will start with the more classical approach of the environmental health impact assessment, by discussing the relevant physical environmental factors (listed in Table 1) separately. At the end of the chapter, the Council will synthesize its findings using the integrative perspective just described.

Table 1 Environmental factors related to the construction and operation of wind turbines and wind farms discussed in section 2.2, apart from changes in landscape.

Factor
Noise (including low frequency noise, infrasound and vibrations)
Shadow flicker
Electromagnetic fields
Accidents
Bird and bat mortality
Disturbance during construction

2.2 Impact of wind turbine operation on health and well-being

In this section, the SHC discusses the evidence on the impact of wind turbine and wind farm operation on the health and well-being of people living in the neighbourhood. The section is organised following the factors listed in Table 1. Occupational risks are mentioned, but not reviewed. The term *effect* is used to denote the reaction of a human to the exposure to an environmental factor related to a wind turbine. *Response* denotes the proportion of an exposed population group in which a given effect is induced by the exposure (Gezondheidsraad: Commissie Afleiding gezondheidskundige advieswaarden 1996). At the end of the section, the interplay between the various factors and the process of deciding upon the siting of wind turbines and their operation is discussed.

2.2.1 Sound (including low frequency sound, infrasound and vibrations)

Terminology

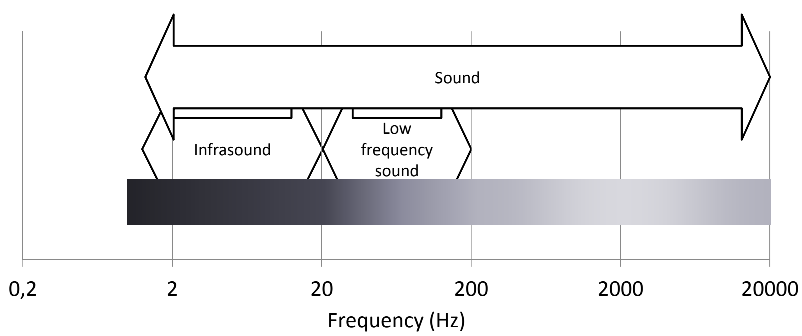

Figure 3 Classification of sound as a function of frequency.

Sound is described as propagating pressure changes in air (or other gases or liquids) and is perceived by humans primarily through the hearing organ.[7] The upper frequency limit of audible sound is in the neighbourhood of 20 kHz[8]. With aging, this value is gradually reduced. Furthermore, the hearing threshold — defined as the lowest sound pressure level that the human ear can detect at a given frequency — tends to increase with age. It is customary to denote sound with frequencies from 20 to 200 Hz as low frequency sound and sound below 20 Hz (to roughly 1 Hz) as infrasound, although other classifications have also been proposed (Møller and Pedersen 2004); see Figure 3. Infrasound is often denoted as inaudible, but this is not fully true since this sound may be detected if the level is sufficiently high, further depending on individual characteristics.

Noise is generally defined as unwanted sound (WHO 1999). The sound or noise level is expressed on a logarithmic scale[9] and often adjusted for the perceived loudness of the sound. The adjusted values are usually followed by 'dB(A)' indicating the logarithmic nature (dB, decibel) and the adjustment by the A-weighing or the A-correction. Sound levels can pertain to a specific sound event, its maximum or average value, or to average exposure levels over parts of the day, months or a year. The EU Environmental Noise Directive proposes two metrics for sound exposure: L_{den} and L_{night} (EU 2002). The noise exposure metric L_{den} represents the daily outdoor noise exposure over a year and takes into account that evening noise is considered more annoying than daytime noise and night-time noise more annoying than evening noise. The noise exposure metric L_{night} represents the outdoor noise exposure over a year during night hours (23-07 h).

Wind turbine sound

Different sounds can be heard near modern wind turbines (Fronz *et al* 2002, Bolin *et al* 2011). The mechanical system (drive train, generator and occasional operation of the yaw system) produces sound that can have tonal components. It is generally lower in level than the aerodynamic sound related to the movement of the rotor blades. The fast movement of the blade tip through the air produces turbulent sound over a broad frequency range that is modulated in amplitude at the rate of the rotating blades (van den Berg 2011). This amplitude modulated sound is expected to be more clearly audible in certain directions (Bowdler 2008, Oerlemans and Schepers 2009) and at night when other sounds usually are less loud than in daytime (van den Berg 2006). Atmospheric turbulence might influence the low frequency component of the sound and could contribute to the particular sound referred to as 'airplane noise' by people living near wind farms. The operation of the wind turbine may also generate low frequency sound, infrasound and vibrations. With sensitive detectors vibrations have been measured in the 2 to 50 Hz frequency region, that were interpreted as due to the rotating blades (Styles *et al* 2005)[10]. At very low frequency, the atmospheric turbulence carried by the wind can also be picked up by the microphone and the human ear, a phenomenon sometimes called pseudo-sound. The amount of atmospheric turbulence can change in the wake of the wind turbine. The vibrations are of very low intensity and not expected to be perceived in neighbouring dwellings.

With increasing size of wind turbines the low frequency fraction of emitted sound power is expected to increase (Møller and Pedersen 2011). As sound of low frequency is absorbed to a

---

[7] Only at high levels airborne sound can also be perceived through body vibrations, including skull conduction.

[8] Hz: hertz, unit of frequency (1 Hz = 1 s^{-1} or 1 per second); kHz: kilohertz, 1 thousand (10^3) hertz

[9] The sound level or sound pressure level is defined as 20 times the 10-logarithm of the ratio of the sound pressure and a reference sound pressure (20 micropascal). The resulting values are usually appended by 'dB' (decibel) to denote the logarithmic nature of the quantity.

[10] The measurements referred to (Styles *et al* 2005) were performed to check the interference of wind farms in Scotland with seismic measuring stations that should detect (nuclear) explosions anywhere on the globe.

lesser extent in air than sound with higher frequencies, it may become more prominent at the facade of dwellings in the vicinity of a wind turbine of wind farm. Moreover building insulation and indoor sound absorption generally decreases at low frequencies.

Box 1 Effects of environmental noise exposure on health and well-being.

The effects of occupational and of environmental noise exposure have been studied extensively. Main environmental noise sources are road, rail and aircraft traffic and industry. Wind turbines are also a source of environmental noise exposure for people living in the vicinity of the wind turbine or wind farm. Specific studies on the effects of wind turbine noise exposure on people are scarce.

Various reports have reviewed the effects of noise on health and well-being (Health Council of the Netherlands: Committee on Noise and Health 1994, WHO 1999, Passchier-Vermeer and Passchier 2000, WHO-Europe 2009, Hoge Gezondheidsraad 2011). The evidence is predominantly based on transport noise exposure. The main effects are annoyance and sleep disturbance and at the higher exposure levels an increase in hypertension and risk of ischaemic heart disease. Noise can also have cognitive and social effects. Occupational noise exposure, with levels higher than environmental noise levels, have been found to affect hearing (Health Council of the Netherlands: Committee on Noise and Health 1994).

The underlying mechanisms leading to these effects, apart from noise induced hearing loss, are slowly being understood by the scientific community (Babisch 2006, Anonymus 2007b, a). Two main pathways are generally recognized. Firstly, sounds affect the organism by evoking autonomic reactions. A sound reaching the ear during sleep immediately increases blood pressure, ventilation (breathing), and heart rate and decreases peripheral blood flow, yet the effect is in many cases immediately followed by an inhibition of the sympathetic excitation. If not, awakening is observed (Gezondheidsraad 2004, Basner *et al* 2008). This short term influence depends on the characteristics of the sound such as rise time and spectro-temporal features that make it stand out above the more continuous background level that the organism has adapted to.

Secondly, environmental sound influences stress (Babisch 2006) and mental restoration (Hartig *et al* 2003). Cognitive (and emotional) processes play an important role (Stallen 1999). The sound is identified and appraised with respect to expectations. Expectations are formed by general characteristics of the environment, prior experience, individual and collective benefits, and the resonance of discourse in society. A chronic condition of stress and deprivation of restorative moments could lead to long term health effects. Significant differences have been observed between individuals. These differences do have an individual and in part a psychological background, and are related to the expectations of people with respect to the noise source and exposures (Heinonen-Guzejev *et al* 2007). But they are also related to factors as age, gender and noise sensitivity. Recent research showed that these differences are partly determined genetically (Heinonen-Guzejev 2009).

At which levels these effects occur for an individual is not certain because of interindividual variability, but population based threshold values have been determined for a number of effects (WHO 1999, WHO-Europe 2009). With respect to transportation noise exposure-response relationships have been derived for annoyance and sleep disturbance (Health Council of the Netherlands: Committee on a Uniform Noise Metric 1997, Miedema and Oudshoorn 2001, Gezondheidsraad 2004, Passchier-Vermeer and Passchier 2005, Hoge Gezondheidsraad 2011). Acoustical characteristics of the noise may cause deviations from these relationships in actual situations. Furthermore, as mentioned above, non-acoustical factors also play a role, implying that the general exposure-response relationships should not be taken for granted in actual situations and may be different for different communities and contexts.

Effects of wind turbine noise exposure

It is plausible that wind turbine noise induces similar effects as described in Box 1, although research data are scarce and mainly concern annoyance and to some extent sleep disturbance (Knopper and Ollson 2011).

The rhythmic character of the sound with a beat frequency of three times the rotor rotational speed[11], makes it particularly noticeable in everyday environmental sound backgrounds, be it more often in the quieter parts of the day, i.e. in the evening and at night. Once attention is focussed on it — and this can be caused by visual cues as well as auditory cues — this sound can easily be detected in relatively strongly masking backgrounds (Pedersen *et al* 2010). Low frequency turbulence sound, another typical sound sometimes recorded near wind turbines, also has detectable features. As noticing a sound is a prerequisite for getting annoyed by it, the higher noticeability of wind turbine sound partly explains why epidemiologic research shows higher responses for wind turbine noise than for traffic noise with the same equivalent noise level at the facade. Other reasons that have been forwarded are that the sound varies unpredictably with the weather, the often quiet environments of countryside wind farms and the fact that the sound level is — on average — not lower at night.

The limited data on annoyance from wind turbines have been assessed by a Dutch research group that earlier derived exposure-response relationships for transportation noise and noise from stationary sources (Miedema and Oudshoorn 2001, Miedema and Vos 2004). The results for the fraction of the exposed population that is highly annoyed[12] as a function of L_{den} are shown in Figure 4 for transportation sources as well as wind turbines.[13] The relatively high level of annoyance from wind turbine sound may be due to the swishing or beating character of the sound and to other non-acoustical factors (Bolin *et al* 2011, van den Berg 2011, Joshi *et al* 2012). In residential areas wind turbines are expected to generally cause less low frequency noise than road traffic (Bolin *et al* 2011). Furthermore, infrasound produced by a wind turbine cannot be heard by the general population, even when close to a wind turbine (Bolin *et al* 2011, Møller and Pedersen 2011). However, if infrasound contributes to noise annoyance, this is still included in the response (Figure 4) as respondents assessed all sound from a source, including the entire frequency range.

[11] Given the usual three-blade wind turbine

[12] People are considered as 'highly annoyed' when they assess their annoyance on a scale of 0 to 100 above 72.

[13] One might comment that using L_{den}, i.e. a noise level averaged over a year, the annoyance at a given sound level is exaggerated. The noise level is an average of a large sequence of varying sound levels and people are expected to be annoyed by the events with the highest levels. For policy purposes this is not very relevant, as long as similar situations in terms of noise sources are compared.

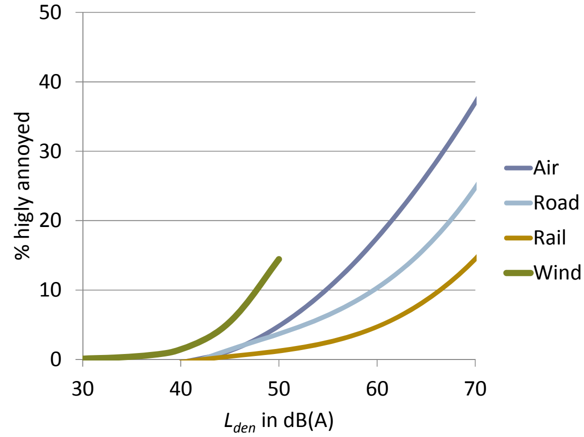

Figure 4 Exposure-response relationships for annoyance indoors from exposure to wind turbine noise, (Janssen et al 2008, Janssen et al 2009) as compared to transportation noise annoyance (Miedema and Oudshoorn 2001).

The data for sleep disturbance are even more limited. The sound produced by wind turbines and hear indoors contains no features that could lead to strong autonomous reactions and awakenings. This does not imply that falling asleep cannot be disturbed by focussing on the sound, as explained below. When wind turbine sound is modulated, i.e. has a rhythmic quality, this 'beating' makes it more conspicuous as explained above. If the beats are audible in the bedroom and just above the sleep disturbance threshold, the high number of beats leads to a relatively high probability of sleep disturbance (van den Berg 2011). The available evidence indicates that, at a given sound level, relatively more people report disturbed sleep[14] due to wind turbine noise than to road traffic noise (Figure 5). Investigations using more objective ways to register sleep disturbance, that have been performed for transport noise exposure during sleep (Passchier-Vermeer and Passchier 2005), are lacking for residents living near wind turbines.

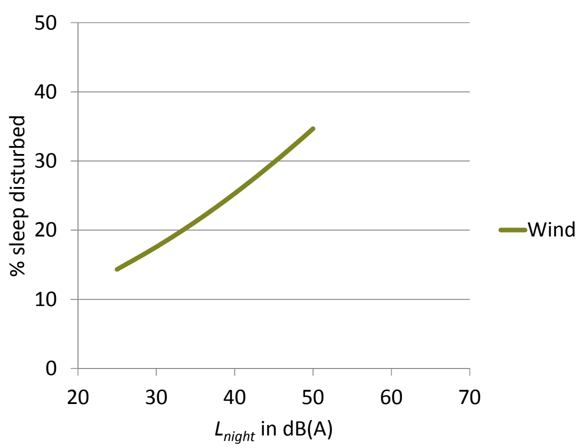

Figure 5 Exposure-response relationships for sleep disturbance annoyance from exposure to wind turbine noise (Janssen et al 2008).[14]

As indicated above annoyance and sleep disturbance related to operating wind turbines have been found in surveys (van den Berg 2011). The SHC stresses that the curves in Figure 4 and Figure 5 should be considered as indicative and are not suitable for assessments in specific locations. The actual average response in a community will vary with factors such as noise

[14] Figure 5 is based on a study where people are considered as 'sleep disturbed' when they reported to be disturbed in their sleep by sound once a month or more often.(Janssen *et al* 2008).

sensitivity, life style, background level, the general attitude to the wind energy, the attitude to the particular project, the presence or absence of local benefits from the project and age (van den Berg 2011).

As yet no study investigated the relationship between wind turbine noise exposure and other health endpoints such as ischaemic heart disease (Knopper and Ollson 2011). Some case reports suggest that symptoms of stress occur in the population, though in a relatively small number of people (Harry 2007, Pierpont 2009) (reviewed in (van den Berg 2011)). The absence of scientific data is probably due to the as yet limited size of the exposed population and the relatively limited exposure time (these other endpoints would take many years to show up, if at all). However, if noise is related to ischaemic heart disease through contributing to stress, the higher level of reported annoyance observed for wind turbine noise, could also lead to an increased risk for this health effect.

The WHO has published guidelines for community noise in 1999 (WHO 1999). New guidelines for night-time noise were issued by WHO Europe in 2009 (WHO-Europe 2009). The values, roughly speaking 50 dB(A) for daily noise exposure and sound levels of 40 dB(A) for night-time noise exposure, pertain to the noise level at the façade of a dwelling (outdoors). They are not thresholds below which no effect in any person is expected to occur, but levels above which effects can be detected in the general population in observational research[15]. As indicated in Figure 4 and Figure 5, the response to wind turbine noise may be larger than to other types of common residential noise. The WHO report also mentions that a special characteristic of a sound, such as the variation over time, a large proportion of low frequency components or a low background sound level, may increase annoyance and thus is an indication for lowering the guideline values (WHO 1999). This apparently applies to wind turbine noise given its high level of annoyance compared to other dominant noise sources (Figure 4). This is probably due, at least in part, to its physical characteristics (amplitude modulation or rhythmic character) and perhaps to the low background sound level in the often quiet environments where wind turbines are operated (Pedersen *et al* 2009). The higher annoyance level is equivalent to a 5 dB higher level of environmental noise (van den Berg 2011), suggesting a 5 dB lower limit compared to these other sources.

The available data make it difficult to identify vulnerable groups. It appears that the age effect for noise annoyance is similar to that found in other noise annoyance studies, i.e. mid-aged people are relatively more annoyed than older or younger people (Miedema and Vos 1999, Janssen *et al* 2008). A group for which there are no data available but that may require further consideration are schoolchildren. In research on aircraft and road noise exposure it has been found that there are negative effects on cognitive performance of schoolchildren, though at significantly higher levels (Clark *et al* 2006, van Kempen *et al* 2010). As these types of noise exposure differ from that of wind turbine noise exposure — typical levels of traffic noise where these effects are observed are generally higher, and the spectro-temporal character of the noise differs — a quantitative comparison is not possible. The WHO guidelines for community noise specify a noise level indoors of 35 dB(A) or less during class hours from environmental noise (1999). People that are noise sensitive or experience feelings of fear in relation to a noise source can be expected to be more annoyed than others. It has been hypothesized that noise sensitive people preferably seek residence in quiet areas which might enhance the effect of wind turbine sound in such areas (Pedersen and Waye 2004). Also, people with hearing problems (such as hyperacusis) and people with a (chronic) illness could be more affected by wind turbines (as they can from other disturbances). However, these characteristics are not related to demographic factors so these individuals cannot be identified as a localized group.

[15] Cf. the definition of 'observation threshold' in (Health Council of the Netherlands: Committee on Noise and Health 1994).

In the literature, it is suggested that low frequency sound and infrasound, even when inaudible cause physiological effects that could lead to health complaints. On the basis of animal experiments (guinea pigs) a hypothesis has been developed that the presence of high frequency sound may inhibit a reaction in the brain to infrasound (Salt and Kaltenbach 2011). The absence of high frequency sounds may thus lead to a biological reaction of (otherwise inaudible) infrasound. As yet it is not clear if this has a noticeable effect on humans and if so, if that is an adverse (health) effect. Also, this has not been reported in the studies where infrasound hearing thresholds have been established and where persons have been exposed to pure infrasound of high level. Furthermore, turbulence in wind produces pressure variations (that are audible as wind rumble when strong enough) that are comparable in frequency and level to that of the infrasound from wind turbines and this has never been reported as adverse to humans (van den Berg 2011). So it is not straightforward whether this attribution of effects to infrasound holds in practice. However, this is not to say that such general health complaints cannot be related to the operation of wind turbines. The SHC refers to the discussion below in 2.2.9.

A 2009 book stated that infrasound and vibrations of wind turbines can cause serious health effects for which the term ‘wind turbine syndrome’ was coined (Pierpont 2009). This statement was based on a study in which people were selected that felt severely affected by the presence of wind turbines, although this procedure is bound to find people who suffer the most, for whatever reason. However the symptoms described — feeling of internal pulsation, quivering or jitteriness, anxiety, fear, compulsion to flee or check the environment for safety, nausea, chest tightness, tachycardia — also occur when persons are exposed to a variety of stressors (van den Berg 2011) and are not specific to low frequency or infrasound. It is clear that the planning history and the noise of a wind farm and the way in which operators and authorities deal with complaints can add to a person’s stress and possibly lead to health complaints (Bowdler 2011). In one of the few field studies on the effects of wind turbine noise it was found that psychological distress was statistically significantly related to noise related annoyance, but not to the noise exposure level (Bakker *et al* 2012), in agreement with the general finding discussed above that environmental noise annoyance is not just determined by the sound level but also by a variety of acoustical and non-acoustical factors.

Vibrations from wind turbines may be generated by the operation of wind turbines and wind farms, but their levels are expected to be low and in many cases they will not be perceived (Styles *et al* 2005, Colby *et al* 2010). The health effects of exposure to vibrations have been studied in occupational settings (Griffin 2006). In those situations, we are confronted with very high accelerations that do not occur in case of exposure to wind turbine generated vibrations (see above). Vibrations can also be annoying; this has been studied in relation to transport, usually in surveys that also asked for noise annoyance (Passchier-Vermeer 1995, Klæboe *et al* 2003, Stansfeld and Matheson 2003). [16] It was found that vibrations and noise do interact, i.e. exposure to vibrations also influences the reported annoyance to the noise. So if people would perceive wind turbine generated vibrations they are expected to show up in the annoyance scores, but this contribution is expected to be low or absent given the prevailing levels.

[16] Citizens may perceive low frequency sound as vibrations and in surveys ascribe their annoyance to vibrations, when they might be exposed to low frequency sound.

2.2.2 Shadow flicker

In sunny conditions, the rotating blades of a wind turbine cast moving shadows on the ground and nearby structures. This phenomenon is termed shadow flicker (NAS-NRC Committee on Environmental Impacts of Wind Energy Projects 2007). It can be annoying for people living close to wind turbines and wind farms. The impact of shadow flicker is determined by local landscape features and sunlight intensity which depends on latitude, zenith angle and cloud cover (NAS-NRC Committee on Environmental Impacts of Wind Energy Projects 2007, Independent Expert Panel 2012). An overview of the literature and guidance in various countries was published in 2011 in the UK (Parsons Brinckerhoff 2011).

Shadow flicker has received more attention in Europe (Germany, Denmark) than in the USA, which may be related to the higher latitudes in the European countries mentioned. In a small field study in Germany it was found that people experiencing more than 15 hours (h) per year of shadow flicker stated that their quality of life was diminished (Pohl *et al* 1999). This study was initiated to provide evidence for a guideline for limiting the calculated exposure to shadow flicker to 30 h per year and 30 minutes per day (ignoring cloud cover)[17] (Nordrhein-Westfalen 2011, Parsons Brinckerhoff 2011). In laboratory research effects on performance were interpreted as due to stress from the exposure (Pohl *et al* 2000).

The perception of shadow flicker also depends on the distance to a wind turbine in relation to its size. For modern wind turbines it will hardly be perceptible at distances over 1000 m (Independent Expert Panel 2012).

Another issue is the possibility of exciting seizures in photosensitive people (NAS-NRC Committee on Environmental Impacts of Wind Energy Projects 2007). This effect depends on the flicker frequency and the intensity between the ‘dark’ and ‘light’ periods. The effects may occur at frequencies above 3 Hz (Erba 2012), but more probably above 10 Hz (NAS-NRC Committee on Environmental Impacts of Wind Energy Projects 2007). As blades of modern, large wind turbines pass at frequencies of less than 1.5 Hz seizures are not expected. Smaller, usually older wind turbines rotate at higher frequencies. Recent (2010) calculations of the relevant viewing parameters for these older wind turbines led to the suggestion that at distances of more than nine times the maximum wind turbine height (shaft and rotor) the seizure risk would be negligible (Smedley *et al* 2010).

It has also been suggested that shadow flicker might be a factor in traffic safety when exposing car drivers (Joshi *et al* 2012), but this is expected to be quite unlikely (Schreuder 1992, UK Highways Agency 2007) (see also 2.2.4).

Blade glint (also called the disco-effect) is the reflection of sunlight by the rotating blade (World Bank 2007). This phenomenon may be annoying for nearby residences. However, it is expected to be negligible when blades have non-reflecting surfaces.

[17] This would imply in practice 8 hours of shadow flicker per year (Nordrhein-Westfalen 2011).

2.2.3 Electromagnetic fields

Wind turbines scatter electromagnetic fields and as such can affect radar and wireless communications (Marsh 2007). This may give rise to problems in air traffic control and so, indirectly, affect aviation safety and thus health. This issue is further discussed in 2.2.4.

The electromagnetic fields produced by the wind turbine equipment are weak. Power lines connecting wind turbine farms to the grid can be sources of (extreme low frequency[18]) electromagnetic fields exposure if they pass close to residences, as is the case near any electricity generation plant.

Some consider the general health complaints described in 2.2.1 in the discussion of low frequency sound and infrasound (Pierpont 2009) as consistent with the phenomenon of electrical hypersensitivity (Havas and Colling 2011). The SHC could not retrieve data that confirm this hypothesis as being specific for the operation of wind turbines. With present day wind turbines and state of the art electricity generation and distribution the Council deems electromagnetic fields not to be an important factor in the discussion of health effects from living near wind turbines and wind farms.

2.2.4 Accident risk

Structural failure

Through quality assurance during construction, adhering to engineering standards and good maintenance during operation, wind turbines are not expected to break down, and if they do, only in rare circumstances. When they break down this may be because of various reasons: the rotor blades may break, the tower may break, the nacelle or rotor hub may fall down or the turbine may catch fire (Braam *et al* 2005, Manwell *et al* 2009). In the first case, the fragments may reach the ground near to the turbine structure or farther away depending on the rotor speed at the time of the accident and the size and original radial position of the fragment. For other breakdowns, the fragments would be deposited within distances less than the height of the wind turbine.

From the data on accidents, accident frequencies have been calculated (Braam *et al* 2005). Failure of the turbine is expected to occur less than once per thousand per year. With a maturing technology, one would expect failure frequencies to become less. On the other hand, new technological developments may counteract such a trend. The effects are usually limited to short distances of the order of magnitude of the maximum turbine height. However, for people being hit by parts of a disintegrating wind turbine the consequences may be deadly. A private database published on the Internet recorded 32 deaths up to 2006 (Gipe 2009). Only a few of them are related to wind turbine failure and most are occupational accidents. Another private database lists 1142 accidents with 99 fatal accidents up to 2011 (Caithness Windfarm Information Forum 2012). Here again most fatalities were among workers working on or near the wind turbine.

Safety criteria for wind turbines and wind farms, when established, usually follow those for hazardous installations (see e.g. (Braam *et al* 2005)). This approach is followed in Flanders (Gorrens and De Clerck 2007). For wind turbines an environmental license is required and a safety case has to be appended to the license application. For inhabited areas, for example, a maximum individual risk[19] of 1 in a million per year is prescribed from which safety distances can be calculated. Indirect risks — impacts on nearby industrial installations — also have to be

---

[18] Mainly 50 (Europe) or 60 (USA) Hz.

[19] Individual risk: the probability that someone at a given location would die from the activity when being exposed for a full year. Denoted in the Flemish regulations as ‘plaatsgebonden risico’.

calculated, in particular for Seveso-installations. The failing fraction of nearby installations should not increase by more than 10 %.

Two other aspects require attention. One is the possibility that the failure of one wind turbine may lead to that of another in wind farms. This risk may be counteracted by adequate design of the wind farm. The other is the shedding of ice from the rotor blades (Tammelin and Seifert 2001, Chatham-Kent 2008). Here again risk distances are relative close to the turbine. Technical measures may prevent the formation of ice sheets on the rotor blades (Tammelin and Seifert 2001). In Flanders an ice-detection system is required; a wind turbine may only operate when any ice detected has been removed (Vlaamse Regering 2012).

These accident risks only affect health when an accident occurs and people are in the vicinity of the failing wind turbine. However, the possibility of an accident may also induce fear and in this way impact on quality of life.

Road traffic safety

Apart from structural failure of the wind turbine, the question has been raised whether the operation of a wind turbine or wind farm would affect traffic safety (Joshi *et al* 2012). The SHC could not identify published studies on the interaction of wind turbines or wind farms with traffic safety on nearby roads. An older (1992) Dutch report, which is still considered relevant, presented pertinent considerations on this issue (Schreuder 1992, UK Highways Agency 2007). The report discussed the above mentioned ice shedding and structural failures and aspects not or only partly specific for wind turbines: crashes of vehicles with wind turbines, turbulence, noise, light effects, distraction and fright. Based on research not related to wind turbines the impact of these aspects is discussed, as well as possibilities for reducing associated risks. The most pertinent recommendation is related to crashes with wind turbines when a motorized vehicle accidentally gets off-road: the report suggests minimum distances between the road and the wind turbine(s) and protective structures to diminish the impact of the crash. Two small traffic accident studies are reported comparing the accident frequency before and after the siting of a series of wind turbines. The results did not indicate a wind turbine related increase in accidents (if anything a decrease), but pertinent conclusions could not be drawn given the small size of the studies.

In general the operation of wind turbines or wind farms is not expected to affect traffic safety in a specific way. When road users might be unexpectedly confronted with wind turbines a warning sign may be in order.

Aviation safety

In 2.2.3 the SHC mentioned interference of wind turbine operation with electromagnetic communication signals, in particular from civil and air defence radar systems (Marsh 2007). Technically, operating wind turbines can cause ‘clutter’ on the radar screens of air traffic control and complicate the safe control of aircraft on their way to or from a nearby airport. Although some busy civil airports appear not to experience problems (Marsh 2007), elsewhere mitigation measures have been proposed to reduce this risk (Brenner 2008). These include restrictions on siting of the wind farms near airports, software to filter out the unwanted wind farm signals and making the wind turbines ‘invisible’ using ‘stealth’ technology (Brenner 2008, Anonymus 2009). In any case, interference with air traffic radar appears to be a risk that can be reduced to acceptable or even negligible levels.

2.2.5 Ecological effects

Although the SHC, consistent with its mission, focuses on human health issues, ecological impacts of wind turbines and wind farms are shortly mentioned here. The information in this section is based on a review of the National Research Council of the National Academies of the USA (NAS-NRC Committee on Environmental Impacts of Wind Energy Projects 2007). The information and conclusions in that report (2007) are still relevant today.

The authors of the American report concluded that wind turbines and wind farms so far have resulted in adverse effects on ecosystem structure and functioning. This is related to the impact of the wind turbine and in particular wind farm infrastructure on the local natural system that will have consequences for the habitat of the species in that system. Another main ecological effect is the killing of passerines, raptors and bats through collisions, most probably with the turbine blades or from the turbulent vortices behind a turbine. There will be differences between migrating and nesting birds. The report also concluded that data are quite scarce and that ecological monitoring should be performed at each new location in order to assess the nature and extent of possible ecological effects.

That recommendation was recently underpinned by a study in which it was found that models to predict bird or bat fatalities did not correlate well with actual data (Ferrer *et al* 2012). Also the Netherlands Commission for Environmental Assessment recommends ecological monitoring in new wind energy projects (Commissie voor de milieueffectrapportage 2010).

2.2.6 Landscape changes

The construction and operation[20] of a wind turbine and in particular of a wind farm will change the visual quality of the environment. This was recently documented for a variety of landscapes in Belgium (Van Rompaey *et al* 2010). From a nationwide survey using pictures of various landscapes the authors derived a visual quality index that appeared to depend on the percentage of forest (positive), percentage of built up area (negative), the hilliness (+) or flatness (-), and the absence of anthropological elements (+) in the landscape. Manipulating the pictures to include wind turbines they could also derive a relationship between the change in visual quality due to the wind turbines and the original value of the visual quality index. The siting of wind turbines affected the visual quality either negatively or positively, according to the survey, with low quality landscapes being improved and high quality landscapes being degraded. Such an index and its dependence on the introduction of wind turbines into the landscape are useful for a first assessment of the impact of new developments. However, in a specific situation the way in which the visual quality of the environment is affected may differ from the prediction. This may be due to landscape characteristics that are not taken into account or that affect a given location differently. Furthermore, not all people qualify the visual quality of an environment identically. The authors noted differences between men and women, between older and younger people and between Flemings and Walloons. Also, the appearance of wind turbines includes the blade movement, which is not captured by static pictures.

Why does visual quality matter? The SHC points to two aspects. People become attached to the place where they live. The siting of a wind turbine or wind farm in their ‘place’ may be felt, at least by some, as intrusion and deterioration of that ‘place’ (Devine-Wright 2005, Devine-Wright and Howes 2010, Haggett 2011, Pasqualetti 2011). This will influence the noise annoyance as was discussed above and affect their quality of life as is further discussed below. The other aspect is related to natural landscapes (Pasqualetti 2011). Natural or ‘green’ areas may positively affect health in providing space for restoration (Gezondheidsraad en Raad voor Ruimtelijk, Milieu- en Natuuronderzoek 2004). Siting a wind farm in such areas may counteract such effects. It is not

[20] One might think of infrastructure changes, such as access roads.

possible or at least quite difficult to quantify these effects, even in a specific situation. However, these aspects should in any case be assessed qualitatively as part of the siting procedure.

2.2.7 Disturbance during construction

As with any new installation, the construction of a wind farm will impact on the quality of life of the people living nearby. Construction works increase traffic of heavy vehicles, generate noise and air pollution and accessibility may become restricted. In addition, accidents may happen that involve the local community. Communities should be informed in a realistic way about such effects, which of course are quite location-specific. A positive effect may be the employment that is provided to the local community if they are involved in construction and maintenance.

2.2.8 Occupational health risks

During construction and operation of a wind turbine or wind farm, worker's health may be affected. Modern wind turbines should be considered as an emerging technology, be it that many of the associated occupational risks are known from other technologies (Ellwood *et al* 2011). As mentioned above (2.2.4), most of the wind turbine related deaths registered in private databases available on the Internet are related to construction and maintenance workers or to workers nearby (Gipe 2009, Caithness Windfarm Information Forum 2012). As the present report focuses on health risk for the general population these risks are not discussed further. Some more information can be obtained from (World Bank 2007, Galman 2009, Jervis 2009).

2.2.9 Quality of life

'Not In My BackYard'

Although renewable energy in general and wind energy in particular is supported by a large fraction of the population (2.1.3, 2.1.4), controversies arise when developing actual wind turbine and wind farm projects, both abroad and in Belgium (2.1.4). Some denote the protests as egoistic, irrational NIMBY-behaviour. One speaks of NIMBY-behaviour ('Not In My BackYard'; see e.g. (Cohen 2001)) when people have no objection against a certain activity (or even support it) as long as it does not negatively affect their personal living environment; there is often an implication that there is no objection as long as others are affected.

However, there is a consensus in the social and environmental science literature that it is incorrect to denote protests against wind turbines as NIMBY-behaviour (Devine-Wright 2005, Wolsink 2007a, Nadaï and Labussière 2010, Swofford and Slattery 2010). This simplistic 'explanation' should be disqualified for different reasons. Firstly, a study realized near three wind turbines farms in the Netherlands showed that *free rider* NIMBY-behaviour was in fact very rare (Wolsink 2000). People opposing the siting of a wind turbines park near their house were in fact more generally opposed to wind turbines siting anywhere. Secondly, "the concept simply does not allow any distinction to be made among the broad range of attitudes" (Wolsink 2000). By labelling all protests as 'NIMBY' one might miss the multitude of underlying motivations, as was found in research on new housing projects in the USA (Pendall 1999). NIMBY-behaviour is not a relevant frame to explain protests against wind turbines. Other factors influencing people perceptions about wind turbines, as discussed below, should be considered.

Quality of community life

Interrelations between different factors may be the best way to understand people's feelings and the socio-psychological impact of wind turbine or wind farm siting and operation on people (Blackburn *et al* 2009). These impacts are linked to the 'quality of life' concept, which encompasses a broad view on health but also takes into account the interactions and interrelationships with the environment (WHO 1946, 1995, RIVM 2000, Ferrans *et al* 2005). This concept is closely related to the concept of mental well-being. Quality of life and mental well-being were considered in the review on the impacts of wind turbines on health and quality of life conducted for the National Public Health Institute of Quebec in 2009 (Blackburn *et al* 2009). Mental well-being was described as: “Mental well-being refers to feelings, cognitive functions, psychological states and impacts linked to the mood and individual behaviour. In the case of wind turbines, possible psychological impact is particularly linked to annoyances”[21]. Social well-being was described as community members’ cohesion and social capital. This refers to the trust between citizens and mutual respect. The factors described in the preceding sections, especially those related to landscape changes (2.2.6), noise perception (2.2.1), shadow flicker (2.2.2) and fear of accidents (2.2.4), impact in an interrelated way on social and mental well-being and thus on the quality of life of individuals and of the community in the neighbourhood of wind turbine and wind farm projects.

Visual and auditory aspects

Loss of auditory (van den Berg 2011) and visual amenity (Gipe 1995, 2002, Good 2006) due to a wind turbine site may have important influence on people’s feelings about the site, as demonstrated by many researchers in Sweden, the Netherlands and the USA (Jobert *et al* 2007). People living near a wind farm or the location of a future farm may be afraid that the continuous exposure to the wind turbine noise (in combination with the other factors discussed in the preceding sections) may impact on their physical or psychological health (Blackburn *et al* 2009). Such concerns are not irrational given our knowledge on the relationship between exposure to these environmental factors and health and well-being. A main effect is annoyance. The authors of a 2011 review paper concluded that “annoyance is not only related to wind turbine noise but also to factors like attitude to visual impact, attitude to wind turbines and sensitivity to noise” (Knopper and Ollson 2011). This finding is in agreement with research on transport noise, where attitudinal factors and noise sensitivity have been shown to determine the level of annoyance together with the noise level (Miedema and Vos 1999, Stallen 1999, Miedema and Vos 2003, De Coensel *et al* 2009). An important aspect of wind turbine related (noise) annoyance is the relationship with landscape changes.

An important factor influencing annoyance is predictability and control of the source. According to Taylor a healthy environment “provides safety, opportunities for social integration, and the ability to predict and/or control aspects of that environment” (Taylor *et al* 1997). In the Dutch survey there was little annoyance amongst respondents with an economical benefit of wind turbines. One of the reasons may be that they have more control over the wind turbines: most of them have taken part in the decision to put up the turbines and they can stop them if they want. A possibility to reduce worry related to the impact of a planned wind farm and annoyance from an operating wind farm is to give residents a measure of control. If residents could decide that ‘their’ wind farm is exceedingly loud and beating on a warm summer night, and stop it or make it operate less loud, this will probably reduce annoyance, partly because of the perceived control and partly because of actually reducing high noise levels.

My place

It is not only the different look of the local landscape due to the wind turbine(s) (sometimes even an improvement as was discussed in 2.2.6) that determines the perception of neighbouring residents of a wind turbine or a wind farm. The level of people’s place attachment and the disruption of that place that may be caused by the wind turbines siting is an important factor to

[21] Our translation of : “L’état de bien-être mental réfère aux émotions, aux fonctions cognitives, aux états psychologiques et aux effets liés à l’humeur, et aux comportements individuels. Dans le cas des éoliennes, l’impact psychologique possible est particulièrement lié aux nuisances” (Blackburn *et al* 2009).

take into account while considering visual perception (Blackburn *et al* 2009). The way “the wind farm threatened place identities for individuals with a strong emotional bond to the place [may lead] to negative attitudes to the project and oppositional behaviour” (Devine-Wright and Howes 2010). For example, in a study on a proposed hydropower project in Norway, it was found that the more strongly local residents felt attached to the affected place, the more negative were the attitudes shown, suggesting that the power station proposal was perceived to disrupt place attachment (Vorkinn and Riese 2001). Similarly, people “who think of wind turbines as ugly are more likely to appraise them as not belonging to the landscape and therefore feel annoyed, also by the noise” (Pedersen and Persson Waye 2007). Place attachment can be very different for people with different uses of and views on their place. A farmer who has to earn a living from his place and a person that moved to the countryside because of the peace and quiet, have a very different perspective. This reinforces the conclusion of the preceding paragraph: visual impact and place attachment seem to be strong predictors of annoyance, apart from the wind turbine noise itself.

Social cohesion

Quality of life depends on the social structure of communities, i.e. community members’ cohesion and social capital (Blackburn *et al* 2009) [22]. Social capital also refers to the trust between citizens and mutual respect. Thus, the way people perceive the promoter of a wind turbines project and the level of trust people give him influence people’s feelings about the wind turbines. “When investors come from outside the community or when higher tiers of government try to site wind power facilities without involving local communities, they may easily create mistrust and the process can be perceived as unfair” (Toke *et al* 2008). The quality of the communication between all the stakeholders (municipalities, promoters, citizens) during the siting and the wind turbines exploitation has also been pointed out as a structuring factor of people’s perceptions about wind turbines farms. This refers to the notion of ‘procedural justice’ as a structuring factor of wind turbines acceptance (Maguire and Lind 2003 , Gross 2007). Annoyances due to the operation of a wind farm and socio-psychological impacts on people may thus be raised by the nature of the relations between stakeholders, and especially between citizens and the promoter (Krohn and Damborg 1999, Gibbs 2000, Wolsink 2000, Nadaï 2007, Wolsink 2007b, a, Wüstenhagen *et al* 2007). These relations are also determined by the way possible effects on health and well-being, reviewed in the preceding sections of this chapter, are discussed. As the Ontario’s Chief Medical Officer highlighted: “community engagement at the outset of planning for wind turbines is important and may alleviate health concerns about wind farms. Concerns about fairness and equity may also influence attitudes towards wind farms and allegations about effects on health” (Chief Medical Officer of Health 2010).

Local economic effects

Finally, the way financial benefits of the wind turbine exploitation are distributed is a factor influencing peoples’ feelings about the wind turbines. Goods redistribution refers to the ‘distributive justice’ principle (Morthorst 1999, Aitken 2010b) and, of course, people may be annoyed by being disadvantaged financially, or quite plausible fear of real estate devaluation because of the siting. They feel themselves involved in an unfair situation, leading to disappointment, mistrust or frustration. Again there is an interrelation with the various factors explored above. Indeed, it has been shown that local population groups receiving economic benefits from wind turbines had decreased levels of noise annoyance than others, despite exposure to similar or even higher sound levels (Pedersen *et al* 2009). So the way the local

---

[22] Social cohesion refers to the bonds between individuals and groups in a society. Social capital can generally be described as the resources in a community that establish family and social organisation. It will contribute to social cohesion (van Kamp 2012).

community wins or loses economically because of a wind turbine project, will co-determine their quality of life.

2.2.10 Conclusion

As highlighted by many authors (Wolsink 2000, Devine-Wright 2007, Wolsink 2007b, Wüstenhagen *et al* 2007, Blackburn *et al* 2009), and especially in recent (2011) studies in Belgium (Fallon *et al* 2011, Pepermans and Loots 2011), what determines quality of life of citizens near wind turbine projects or wind farms is a complex matter. There is no direct evidence for disease, but the SHC acknowledges that research relating the operation of wind turbines to specific diseases is virtually non-existent. However, for modern wind turbines, direct health effects other than annoyance and possibly sleep disturbance are unlikely. Both annoyance and disturbed sleep can however lead to undue stress, which may have negative consequences for the health and well-being of the affected people.

In terms of the broader concept of quality of life, or taking well-being as part of the health concept, a main environmental health effect is annoyance that people relate to the noise from the operating wind turbines, both when awake and during their sleeping period. However, as extensively discussed in 2.2.9, the level of annoyance — both individually and in the population — can only be understood by taking into account other factors, such as the way in which the wind turbines or wind farm change the landscape, intrude on the attachment of people to the local environment and whether any local economic benefits or costs are derived from the wind turbine project.

On the one hand, the resulting perception of (future) quality of life determines the social acceptance of a wind turbine project by a local community. On the other hand, the perception of a (future) loss of quality of life may generate or aggravate health complaints for some people, e.g. feeling depressed, headaches or hypertension.

So in the case of the operation of wind turbines or wind farms, impacts on quality of life, i.e. on health and well-being, can occur, but these depend in a complex and interrelated way on a variety of factors without a simplistic relation with a single specific environmental factor, such as, e.g., the exposure to wind turbine noise or the changed appearance of the landscape.

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 Wind energy

As was discussed in section 2.1, the choice of energy resources is directly and indirectly relevant for public health, both globally and locally. Even though the provision of energy in general and of electricity in particular has large benefits, including public health benefits, the present dominant technologies for energy production are unsustainable. This unsustainability implies that the quality of life, including health, of future generations cannot be guaranteed without changes in energy production. International and national policies therefore strive to replace in particular fossil fuels as energy resources by renewable sources or in any case to increase the proportion of renewables in the energy resource mix. Wind energy is expected to play an important role in this respect. So as part of the transformation towards a more sustainable society electricity production by wind energy has quality of life, including public health, benefits in the long term.

Apart from that, the various ways of electricity production have different environmental health impacts. In the operational phase, wind energy is a clean way of producing electricity, with hardly any emissions from possible health threatening substances. However, a quantitative comparison should take the whole life cycle of the electricity production technology into account. As was indicated in section 2.1, life cycle analyses for the various technologies have been performed. The outcomes are generally positive for wind energy as compared with fossil fuel or nuclear technologies. The SHC recommends that a life cycle study comparing the various electricity generating options and their impacts on public health be performed for the Belgian situation. Expertise gained from such studies in Flanders should be taken into account (Torfs 2003, Nijs *et al* 2011). Furthermore, the difference in the distribution over the population of the benefits and the impacts on health and well-being should be taken into consideration, as well as the impact of low probability accidents with possible high consequences. Also the 'population at risk is unknown. An estimate of the population at risk should be part of the study recommended by the Council.

Recommendation 1 : The SHC recommends performing a life cycle analysis of the various options that are available in Belgium to generate electricity. This analysis should attempt to express their public health impacts both in monetary terms and by using measures of population health such as disability adjusted life years. It should also take into account the distributional effects of the benefits and adverse health effects of these different options. Such a study should include an estimate of the Belgian at-risk population.

3.2 Local impacts of wind turbines

Just like any electricity generation technology, the electricity has to be generated at certain locations. This has local impacts that might affect the quality of life of the population living near the electricity plant, leading to an unequal distribution of 'costs' and 'benefits' among the population in general. These local impacts in the case of wind energy were discussed in section 2.2.

The interpretation of the scarce research data on the local impacts on health and wellbeing (i.e. quality of life) of wind turbines and wind farms is still subject to scientific debate and uncertainty. In deriving its recommendations the SHC therefore has taken a prudent approach in order to safeguard as far as reasonably achievable the quality of life of the residents. This approach is consistent with a precautionary strategy (Gezondheidsraad 2008), which has been advocated by the Council in other advisory reports with a deficient evidence base.

In its conclusion (2.2.10) the SHC identified as main impacts on health and well-being: annoyance and possibly sleep disturbance. The SHC found no convincing evidence from epidemiological investigations for other specific health effects directly related to environmental factors such as vibrations, audible sound, infrasound, electromagnetic fields or light reflections generated by modern wind turbines. However, persisting annoyance and sleep disturbance may lead to other health effects (see 2.2.1 and 2.2.9).

The annoyance is mainly related to the noise produced by the wind turbine operation (for shadow flicker, see below). Tentative noise exposure-response relationships for both annoyance and self-reported sleep disturbance have been presented (2.2.1). However, the annoyance level, both individually and within the population depends not only on the noise level, but on a variety of other factors, related to changes in landscape and intrusion of a wind turbine project in a familiar environment, as well distribution of costs and benefits and trust in the regulatory authorities and the project promoters.

Annoyance and sleep disturbance from a wind turbine or wind farm in operation can possibly not be fully avoided in a densely populated country as Belgium. However, the SHC recommends that at least the fraction of highly annoyed and highly sleep disturbed people be reduced to negligible values. In this respect the Council draws attention to the WHO guidelines for community noise that specify guideline values[23] of 55 dB(A) during day and evening based on 'serious annoyance' and 50 dB(A) based on 'moderate annoyance' (WHO 1999). The WHO-report indicates that due to special characteristics of a noise or a low background sound level a noise may be more annoying and a lower guideline value would be appropriate. Wind turbine noise is apparently more annoying than other environmental noise (see Figure 4) and this added annoyance is roughly equivalent to a 5 dB higher level of environmental noise. Therefore the SHC recommends limiting the daytime noise level to values below 45 dB(A). For night-time noise a guideline value of 45 dB(A) was proposed. The WHO also suggested applying more cautious values when the noise contains an important low frequency component, as is the case with wind turbines.

In a more recent report the latter value was lowered to 40 dB(A) (WHO-Europe 2009). The more recent night-time value was expressed in the noise metric L_{night}, which implies integration over the year. For a noise source with levels that may strongly differ from day to day using this metric may lead to a further lowering of the guideline value as reported annoyance and sleep disturbance is expected to be related to the highest levels.

Although a certain noise level related to wind turbine operation may have different impacts in different situations, given the many factors that affect annoyance and self-reported sleep disturbance, taking account of the considerations above would lead to sound levels that should not be exceeded less than 45 dB(A) for the day. For the night 40 dB(A) should not be exceeded at the most exposed façade of dwellings. Whether the statement in the WHO-Europe document that there "is no sufficient evidence that the biological effects observed at the level below 40 dB $L_{night,outside}$ are harmful to health" also holds for wind turbine noise outside is not certain, so there is reason not to exceed this level especially in otherwise quiet environments.

Recommendation 2 : The SHC recommends that the noise levels due to the operation of wind turbines and wind farms near people's homes should comply with the WHO and WHO Europe guidelines for day-time and night-time noise exposure in order to avoid serious annoyance and (self-reported) sleep disturbance. This would lead to sound levels below 45 dB(A) during day-time and 40 dB(A) at night. If such values are already exceeded by other noise sources, the wind turbine noise contribution might be limited to an unnoticeable increase in noise level, depending on the masking potential of the existing noise levels.

With respect to annoyance from shadow flicker the SHC recommends that any effects be minimized by selecting appropriate wind turbine locations and wind farm design. In case shadow

[23] For the meaning of guideline values, see 2.2.1.

flicker cannot be fully avoided, the Council suggests to apply the German standard of 30 h per year and 30 minutes per day not taking into account cloud cover (Nordrhein-Westfalen 2011).

Recommendation 3 : The SHC recommends that effects from the shadow flicker caused by the operating wind turbines should be avoided by carefully selecting the location and design of wind turbine projects. If shadow flicker cannot be avoided, the Council advises to comply with the North Rhine-Westphalia standard for shadow flicker.

Safety issues related to wind turbine operation were discussed in 2.2.4 and involve structural failures and ice shedding, interference with aviation control and motorized traffic safety on nearby roads. The SHC concludes that those issues can be resolved by appropriate measures, in any case to risk levels that are considered to be acceptable in society.

Recommendation 4 : Safety issues related to wind turbine operation should be taken seriously but can be resolved by means of appropriate measures. These measures include quality control during construction and operation (structural failure), location selection (structural failure and aviation and traffic safety), infrastructure measures (structural failure and traffic safety) and technical measures (aviation safety, ice shedding).

It is not enough to just consider noise levels to reduce annoyance from wind turbine operation. A wind turbine project changes the look of the local environment (in some cases for the better, see 2.2.6). But apart from a different look the implementation of the project may be considered as in intrusion in the environment familiar to local inhabitants and to which they feel attached. These factors are major determinants in feelings of annoyance (2.2.9). These feelings may be reinforced (or weakened) by the process of location selection, project design and project implementation. In addition, local economic benefits (profits from the electricity generation) and costs (depreciation of real estate values) play a role.

Furthermore, giving local residents some say in the day to day operations of a wind turbine or a wind farm may lessen annoyance and annoyance related stress. This has been found in measures related to airports, for example in using alternative flight paths from time to time (Stallen 1999, Maris *et al* 2007); see also (Taylor *et al* 1997).

The SHC therefore recommends consulting stakeholders, in particular those of the local community, to guide project design and implementation. Guidance for such processes can be found in a report of the King Baudouin Foundation and documents referred to in that report (Elliott *et al* 2005). Participatory design and implementation processes for complex projects as the siting and operation of wind turbines and in particular wind farms increase the possibility of the social acceptance of specific projects, although they are no guarantee for a positive outcome, i.e. positive from the point of view of the project promoters.

Recommendation 5 : The SHC recommends that the design and implementation of wind energy projects should be part of a participatory process in which the stakeholders have a real say in the design, the implementation and operation of the project. For such decisions to achieve social acceptance, it is of paramount importance that the outcome of these processes is not settled beforehand. Rather, the stakeholders should have the opportunity of giving their "green light" to the project, request alterations in its design and operation or suggest that the proposed project be abolished.

Even when a wind energy project is socially accepted, the annoyance experienced by some in the local population may lead to a-specific health complaints, such as headaches, sleeplessness and feelings of depression. This is a reason to involve local general practitioners in the participatory process and to provide them with up to date information on impacts on health and well-being of the operation of wind turbines. In this respect it is advisable to include education on environmental health issues, such as related to wind turbines and other energy production projects, in the curriculum for medical students and in the post-university courses for general practitioners.

Recommendation 6** : **The SHC recommends that local general practitioners are provided with up to date information about the impacts of wind turbine operation on health and well-being and take part in the participatory design and implementation process.

Apart from annoyance (noise, shadow-flicker, visual appearance) and sleep disturbance (noise) epidemiological evidence on specific diseases that are associated with the wind turbine operation is absent. In line with the prudent approach mentioned above the SHC recommends that health effects in local communities near wind turbines and in particular wind farms should be monitored. The Council suggests devising periodical surveys in cooperation with local general practitioners and municipal health services. A standardized way for the reporting of complaints would be helpful. By pooling data from different wind turbine projects a knowledge base is developed that may diminish the uncertainties about the health impacts. A special point of attention is the identification of possible vulnerable groups. The Council stresses that monitoring of health complaints is not to be confused with epidemiological research. In most situations the affected populations are simply too small to draw scientifically valid conclusions on the impact of the wind turbine projection in question.

Recommendation 7 : The SHC recommends the health status of the population in the vicinity of wind energy projects should be monitored by means of appropriate methods.

On a more general level, the intensive development of wind energy necessitates an increasing effort in obtaining data on the possible impacts on health and well-being. Such studies can best be performed on a European or even a larger international level. The Council points to a recent initiative of the Canadian government for such a study (Michaud *et al* 2012).

Recommendation 8 : The SHC recommends that Belgium should participate in or take the initiative for an international study on the possible specific impacts of wind turbine operation on the health and well-being of those living in their vicinity.

3.3 Epilogue

The main question posed to the SHC was: can wind energy be implemented on the large scale foreseen in government policies with benefits for public health and no deterioration of health and well-being of citizens living near wind energy projects. The Council's answer is both 'yes' and 'may be'.

The replacement of traditional energy sources by renewable ones will benefit public health both on the short and the long run, although the Council could not detail the expected benefits within the framework of the present report. The 'may be' refers to local impacts. As in Belgium onshore wind turbines and in particular wind farms will generally be located near habitations — given the population density of the country —impacts in terms of annoyance and sleep disturbance are inevitable, although they can be reduced by appropriate location selection and wind farm design.

However, these effects also depend on the implementation process, i.e. on the local social acceptability of a wind energy project. Neglecting this latter aspect will certainly hamper wind energy development, as experiences in other countries demonstrate, and will also negatively influence the health and well-being of the local population.

4 REFERENCES

- ABB. Belgium: Energy efficiency report: ABB; 2011. Internet: http://www05.abb.com/global/scot/scot316.nsf/veritydisplay/f0ed08eaf069a515c12578aa004bf178/$file/belgium.pdf, accessed 09-02-2013.

- Aitken M. Why we still don't understand the social aspects of wind power: A critique of key assumptions within the literature. Energy Policy 2010a;38(4):1834-41.

- Aitken M. Wind power and community benefits: Challenges and opportunities. Energy Policy 2010b;38(10):6066-75.

- Anonymus. Impact assessment. Chapter 6. In: Heimann D, de Franceschi M, Emeis S, Lercher P, Seibert P, editors. Air Pollution, Traffic Noise and Related Health Effects in the Alpine Space − A Guide for Authorities and Consulters. Trento, Italy: Università degli Studi di Trento, Dipartimento di Ingegneria Civile e Ambientale; 2007a. Internet: http://www.alpnap.org/results_en.html, accessed 09-02-2013.

- Anonymus. Noise. Chapter 5. In: Heimann D, de Franceschi M, Emeis S, Lercher P, Seibert P, editors. Air Pollution, Traffic Noise and Related Health Effects in the Alpine Space − A Guide for Authorities and Consulters. Trento, Italy: Università degli Studi di Trento, Dipartimento di Ingegneria Civile e Ambientale; 2007b. Internet: http://www.alpnap.org/results_en.html, accessed 09-02-2013.

- Anonymus. QinetiQ and Vestas test turbine ‘stealth technology’ [news]. Renew Energy Focus 2009;10(6):12.

- Babisch W. Transportation Noise and Cardiovascular Risk. Review and Synthesis of Epidemiological Studies; Dose-effect Curve and Risk Estimation. Dessau, Deutschland: Umweltbundesamt; 2006. WaBoLu-Hefte Nr. 01/2006. Internet: http://www.umweltbundesamt.de/uba-info-medien-e/2997.html, accessed 09-02-2013.

- Bakker RH, Pedersen E, van den Berg GP, Stewart RE, Lok W, Bouma J. Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress. Sci Tot Environ 2012;425:42-51.

- Basner M, Glatz C, Griefahn B, Penzel T, Samel A. Aircraft noise: Effects on macro- and microstructure of sleep. Sleep Med 2008;9(4):382-7.

- Blackburn D, Rodrigue L, Tardif I, Chagnon M, Martel K, Morasse A, et al. Éoliennes et santé publique. Synthèse des connaissances. Québec: Institut National de Santé Publique de Québec; 2009 Septembre. Internet: http://www.inspq.qc.ca/publications/notice.asp?E=p&NumPublication=1015, accessed 09-02-2013.

- Bolin K, Bluhm G, Eriksson G, Nilsson ME. Infrasound and low frequency noise from wind turbines: exposure and health effects. Environ Res Lett 2011;6(3):035103.

- Bowdler D. Amplitude modulation of wind turbine noise. A review of the evidence. Acoustics Bulletin 2008;2008(July/August):31-5.

- Bowdler D. Why Turbine Noise Annoys. Culross, Fife, Scotland2011 April. Paper presented at the Fourth International Meeting on Wind Turbine Noise, Rome Italy, 12-14 April 2011.

- Braam H, van Mulekom GJ, Smit RW. Handboek risicozonering windturbines. Den Haag: SenterNovem; 2005. Internet: http://www.windenergie.nl/onderwerpen/milieu-en-omgeving/risicozonering, accessed 09-03-2013.

- Brenner M. Wind Farms and Radar. McLean, VA, USA: JASON, The MITRE Corporation; 2008 January. Report JSR 08-125. Internet: http://www.fas.org/irp/agency/dod/jason/wind.pdf, accessed 09-03-2013.

- Caithness Windfarm Information Forum. Summary of Wind Turbine Accident data to 31st December 2011: Caithness Windfarm Information Forum; 2012. Internet: http://www.caithnesswindfarms.co.uk/page4.htm, accessed 09-03-2013.

- Chatham-Kent. The Health Impact of Wind Turbines: A Review of the Current White, Grey, and Published Literature. Chatham, Ontario, Canada: Chatham-Kent Public Health Unit; 2008 June. Internet: http://www.apho.org.uk/resource/item.aspx?RID=111670, accessed 09-02-2013.

- Chief Medical Officer of Health. The Potential Health Impact of Wind Turbines. Ontario: Ministry of Health and Long-Term Care; 2010 May. Internet: http://www.health.gov.on.ca/en/common/ministry/publications/reports/wind_turbine/wind_turbine.aspx, accessed 09-02-2013.

- Clark C, Martin R, van Kempen E, Alfred T, Head J, Davies HW, et al. Exposure-Effect Relations between Aircraft and Road Traffic Noise Exposure at School and Reading Comprehension: The RANCH Project. Am J Epidemiol 2006;163(1):27-37.

- Cohen R. Britain Goes Nimby. The New York Times. 2001 August 26.

- Colby WD, Dobie R, Leventhall G, Lipscomb DM, McCunney RJ, Seilo MT, et al. Le son des éoliennes et ses répercussions sur la santé: American Wind Energy Association/Canadian Wind Energy Association; 2010 juin. Examen d'un comité d'experts. Internet: http://www.bape.gouv.qc.ca/sections/mandats/eole-monteregie/documents/DM15.2.pdf, accessed 09-02-2013..

- Commissie voor de milieueffectrapportage. Windparken Noordoostpolder. Toetsingsadvies over het milieueffectrapport en de aanvulling daarop. Utrecht: Commissie voor de milieueffectrapportage; 2010 maart 24. Rapportnummer 2352-115. Internet: http://www.commissiemer.nl/zoeken/126872?q=%22noordoostpolder%22&dt=jurisprudentie%7Ctoetsingsadviezen, accessed 09-02-2013.

- Corvalan C, Hales S, McMichael A. Ecosystems and human well-being. Health synthesis. Geneva: World Health Organization; 2005. A Report of the Millennium Ecosystem Assessment. Internet: http://www.who.int/globalchange/ecosystems/ecosystems05/en/index.html, accessed 09-02-2013.

- D'Souza N, Gbegbaje-Das E, Shonfield P. Life Cycle Assessment Of Electricity Production from a Vestas V112 Turbine Wind Plant. Copenhagen: PE North West Europe ApS; 2011 February. FInal report. Internet: http://www.vestas.com/Admin/Public/DWSDownload.aspx?File=%2fFiles%2fFiler%2fEN%2fSustainability%2fLCA%2fLCA_V112_Study_Report_2011.pdf, accessed 09-02-2013.

- Davidsson S, Höök M, Wall G. A review of life cycle assessments on wind energy systems. Int J Life Cycle Ass 2012;17(6):729-42.

- De Coensel B, Botteldooren D, De Muer T, Berglund B, Nilsson ME, Lercher P. A model for the perception of environmental sound based on notice-events. J Acoust Soc Am 2009;126(2):656-65.

- de Hollander AEM. Assessing and evaluating the health impact of environmental exposures "Deaths, DALYs or Dollars?" [PhD Thesis]. Utrecht: Universiteit Utrecht; 2004.

- de Hollander AEM, Lebret E. Definitierapport Graadmeters Volksgezondheid in de Milieubalans/Milieuverkenning (1e versie). Bilthoven: RIVM; 1994. RIVM Rapport 482516003.

- de Hollander AEM, Melse JM, Lebret E, Kramers PG. An aggregate public health indicator to represent the impact of multiple environmental exposures. Epidemiol 1999;10(5):606-17.

- Devine-Wright P. Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. Wind Energy 2005;8(2):125-39.

- Devine-Wright P. Reconsidering public attitudes and public acceptance of renewable energy technologies : a critical review Manchester, UK: University of Manchester, Manchester Architecture Research Centre; 2007. Working Paper 1.4. A working paper of the research project “Beyond Nimbyism: a multidisciplinary investigation of public engagement with renewable energy technologies” funded by the ESRC under the ‘Towards a Sustainable Energy Economy’ Programme. Internet: http://www.esrc.ac.uk/my-esrc/grants/RES-152-25-1008-A/outputs/Read/84df5b36-a73c-408c-9a3c-35e7d299d6c3, accessed 09-02-2013.

- Devine-Wright P, Howes Y. Disruption to place attachment and the protection of restorative environments: A wind energy case study. J Environ Psychol 2010;30(3):271-80.

- Elliott J, Heesterbeek S, Lukensmeyer CJ, Slocum N. Participatory Methods Toolkit. A practitioner's manual [New edition]. Brussel: King Baudouin Foundation and the Flemish Institute for Science and Technology Assessment (viWTA); 2005 September. Internet: http://www.kbs-frb.be/publication.aspx?id=294864&langtype=1033, accessed 09-02-2013.

- Ellwood P, Bradbrook S, Reynolds J, Duckworth M. Foresight of New and Emerging Risks to Occupational Safety and Health Associated with New Technologies in Green Jobs by 2020 - PHASE II – KEY TECHNOLOGIES. Bilbao, Spain: European Agency for Safety and Health at Work; 2011. Internet: http://osha.europa.eu/en/publications/reports/foresight-green-jobs-key-technologies, accessed 09-02-2013.

- ENOVER-CONCERE. België: Nationaal actieplan voor hernieuwbare energie overeenkomstig Richtlijn 2009/28/EG2010 november. Opgesteld door de Energie Overleggroep Staat-Gewesten ENOVER/CONCERE. Internet: http://www2.vlaanderen.be/economie/energiesparen/milieuvriendelijke/Nuttige_documenten/Nationaal_actieplan_HE.pdf, accessed 09-02-2013.

- Erba G. Shedding Light on Photosensitivity, One of Epilepsy’s Most Complex Conditions: Epilepsy Foundation; 2012. Internet: http://www.epilepsyfoundation.org/aboutepilepsy/seizures/photosensitivity/gerba.cfm, accessed 09-02-2013.

- EU. 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 [Richtlijn 2002/49/EG van het Europees Parlement en de Raad van 25 juni 2002 inzake de evaluatie en de beheersing van omgevingslawaai]. Official Journal of the European Communities 2002;L189(18.7.2002):12-25.

- EU. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Official Journal of the European Union 2009;L 140(5.6.2009):16-62.

- European Commission. Energy Technologies: Knowledge, Perception, Measures. Luxembourg: European Commission; 2006. Eurobarometer. Document EUR 22396. Internet: http://ec.europa.eu/research/energy/pdf/energy_tech_eurobarometer_en.pdf, accessed 09-02-2013.

- European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Energy Roadmap 2050. Brussels: European Commission; 2011 December 15. Document COM(2011) 885 final. Internet: http://ec.europa.eu/energy/energy2020/roadmap/index_en.htm, accessed 09-02-2013.

- European Wind Energy Association. Wind Energy. The Facts. Brussels: European Wind Energy Association; 2009 March. Internet: http://www.wind-energy-the-facts.org/en/home--about-the-project.html, accessed 09-02-2013.

- ExternE. ExternE. Externalities of Energy - Methodology 2005 Update. Brussels: European Commission, Directorate-General for Research; 2005. Publication nr. EUR21951. Internet: http://www.externe.info/, accessed 09-02-2013.

- Fallon C, Parotte C, Rossignol N. Acceptabilité locale des projets éoliens. Liège: Université de Liège, Spiral; 2011 octobre. Internet: http://orbi.ulg.ac.be/handle/2268/108764, accessed 09-02-2013.

- Ferrans CE, Zerwic JJ, Wilbur JE, Larson JL. Conceptual Model of Health-Related Quality of Life. J Nurs Scholarship 2005;37(4):336-42.

- Ferrer M, de Lucas M, Janss GFE, Casado E, Muñoz AR, Bechard MJ, et al. Weak relationship between risk assessment studies and recorded mortality in wind farms. J Appl Ecol 2012;49(1):38-46.

- Fronz W, Piorr D, Kindel R. Windenergieanlagen und Immissionsschutz. Essen, Deutschland: Landesumweltamt Nordrhein-Westfalen; 2002. Materialien Band Nr. 63. Internet: http://www.lanuv.nrw.de/veroeffentlichungen/materialien/mat63/mat63start.htm, accessed 09-02-2013.

- Galman D. Cultivating Safety at Wind Farms. Occup Health Saf 2009;78(1):28.

- Gezondheidsraad. Over de invloed van geluid op de slaap en de gezondheid [The Influence of Night-time Noise on Sleep and Health]. Den Haag: Gezondheidsraad; 2004. Publicatie nr 2000/14. Internet: http://www.gezondheidsraad.nl/nl/adviezen/over-de-invloed-van-geluid-op-de-slaap-en-de-gezondheid, accessed 09-02-2013.

- Gezondheidsraad. Maten voor milieugezondheidseffecten. Den Haag: Gezondheidsraad; 2007 oktober 16. Publicatie nr 2007/21. Internet: http://www.gezondheidsraad.nl/nl/adviezen/maten-voor-milieugezondheidseffecten, accessed 09-02-2013.

- Gezondheidsraad. Voorzorg met rede [Prudent precaution]. Den Haag: Gezondheidsraad; 2008 september 26. Publicatie nr 2008/18. Internet: http://www.gezondheidsraad.nl/nl/adviezen/voorzorg-met-rede, accessed 09-02-2013.

- Gezondheidsraad, Raad voor Ruimtelijk, Milieu- en Natuuronderzoek. Natuur en gezondheid. Invloed van natuur op sociaal, psychisch en lichamelijk welbevinden [Nature and Health. The influence of nature on social, psychological and physical well-being]. Den Haag: Gezondheidsraad, Raad voor Ruimtelijk, Milieu- en Natuuronderzoek; 2004. Publicatie Gezondheidsraad nr 2004/09, publicatie RMNO nr A02a. Internet: http://www.gezondheidsraad.nl/nl/adviezen/natuur-en-gezondheid-invloed-van-natuur-op-sociaal-psychisch-en-lichamelijk-welbevinden, accessed 25-06-2012.

- Gezondheidsraad: Commissie Afleiding gezondheidskundige advieswaarden. Toxicologische advieswaarden voor blootstelling aan stoffen. Den Haag: Gezondheidsraad; 1996 augustus 29. Publicatie nr 1996/12. Internet: http://www.gezondheidsraad.nl/nl/adviezen/toxicologische-advieswaarden-voor-blootstelling-aan-stoffen, accessed 09-02-2013.

- Gibbs D. Ecological modernisation, regional economic development and regional development agencies. Geoforum 2000;31(1):9-19.

- Gipe P. Design As If People Matter: Aesthetic Guidelines for the Wind Industry1995. Paper presented at the American Wind Energy Association's conference in Washington, DC, March 30, 1995. Internet: http://www.wind-works.org/articles/design.html, accessed 09-02-2013.

- Gipe P. Design As If People Matter: Aesthetic Guidelines for a Wind Power Future. Chapter 9. In: Pasqualetti MJ, Gipe P, Righter RW, editors. Wind Power in View. San Diego, CA: Academic Press; 2002. p. 173-212.

- Gipe P. Wind Energy -- The Breath of Life or the Kiss of Death: Contemporary Wind Mortality Rates2009. Internet: http://www.wind-works.org/articles/BreathLife.html, accessed 09-02-2013.

- Good J. The Aesthetics of Wind Energy. Hum Ecol Rev 2006;13(1):76-89.

- Gorrens B, De Clerck W. Studie windturbines en veiligheid. Brussel: Vlaams Energieagentschap; 2007 januari. Eindrapport. Internet: http://www.apere.org/manager/docnum/doc/doc1286_veiligheid.fiche111.pdf, accessed 09-02-2013.

- Gouvernment Wallon. La Wallonie se dote d’un nouveau cadre éolien ! Jambes, Belgique: Gouvernement Wallon; 2011 septembre 1. Internet: http://gouvernement.wallonie.be/nouveau-cadre-olien-en-wallonie-0, accessed 09-02-2013.

- Griffin MJ. Health Effects of Vibration - The Known and the Unknown. In: Dong R, Krajnak K, Wirth O, Wu J, editors. Proceedings of the First American Conference on Human Vibration, 5-7-July 2006, Morgantown, West Virginia. Cincinnati, OH: National Institute for Occupational Safety and Health; 2006. p. 3-4. Internet: http://eprints.soton.ac.uk/45678/, accessed 09-02-2013.

- Gross C. Community perspectives of wind energy in Australia: The application of a justice and community fairness framework to increase social acceptance. Energy Policy 2007;35(5):2727-36.

- Haggett C. Understanding public responses to offshore wind power. Energy Policy 2011;39(2):503-10.

- Harry A. Wind Turbines, Noise and Health. Rowe, MA, USA: National Wind Watch; 2007 February. Internet: http://docs.wind-watch.org/wtnoise_health_2007_a_harry.pdf, accessed 09-02-2013.

- Hartig T, Evans GW, Jamner LD, Davis DS, Gärling T. Tracking restoration in natural and urban field settings. J Environ Psychol 2003;23(2):109-23.

- Havas M, Colling D. Wind Turbines Make Waves: Why Some Residents Near Wind Turbines Become Ill. Bull Sci Technol Soc 2011;XX(X):1-13.

- Health Council of the Netherlands: Committee on a Uniform Noise Metric. Assessing noise exposure for public health purposes [Omgevingslawaai beoordelen]. The Hague: Health Council of the Netherlands; 1997. nr 1997/23E. Internet: http://www.gezondheidsraad.nl/en/publications/assessing-noise-exposure-public-health-purposes, accessed 09-02-2013.

- Health Council of the Netherlands: Committee on Noise and Health. Noise and Health [Geluid en gezondheid]. The Hague: Health Council of the Netherlands; 1994. Publication nr 1994/15E. Internet: http://www.gezondheidsraad.nl/nl/adviezen/geluid-en-gezondheid, accessed 09-02-2013.

- Heinonen-Guzejev M. Noise sensitivity – medical, psychological and genetic aspects [PhD-thesis]. Helsinki, Finland: University of Helsinki; 2009.

- Heinonen-Guzejev M, Vuorinen HS, Mussalo-Rauhamaa H, Heikkila K, Koskenvuo M, Kaprio J. The association of noise sensitivity with coronary heart and cardiovascular mortality among Finnish adults. Sci Total Environ 2007;372(2-3):406-12.

- Herregodts D. 'Vogels zijn blijkbaar belangrijker dan mensen'. Buurt vecht tegen windmolens van Volvo Trucks. Nieuwsblad•be. 2008a mei 24.

- Herregodts D. 'Wij willen een goede buur zijn'. Woordvoerster Vera Bostyn van Volvo Trucks. Nieuwsblad•be. 2008b mei 24.

- Het Nieuwsblad. 'Mooiste dorp' vreest windmolens aan kanaal. Nieuwsblad•be. 2011 mei 13.

- Hoge Gezondheidsraad. Gezond op weg: De milieueffecten van het verkeer op de gezondheid. Brussel: Hoge Gezondheidsraad; 2011. Internet: http://www.health.belgium.be/internet2Prd/groups/public/@public/@shc/documents/ie2divers/19069613.pdf, accessed 09-02-2013.

- Huynen MMTE, de Hollander AEM, Martens P, Mackenbach JP. Mondiale milieuveranderingen en volksgezondheid: stand van de kennis. Bilthoven: Rijksinstituut voor Volksgezondheid en Milieu; 2008. Internet: www.lymevereniging.nl/file.php?id=71, accessed 09-02-2013.

- Independent Expert Panel. Wind Turbine Health Impact Study: Report of Independent Expert Panel. Boston, MA: Massachusetts Department of Environmental Protection; 2012 January. Internet: http://www.mass.gov/dep/energy/wind/impactstudy.htm, accessed 09-02-2013.

- Ipsos. Perception de l'énergie éolienne en Wallonie. Waterloo, Belgique: Ipsos Public Affairs; 2010. Internet: http://edora.org/news.php?id_news=32, accessed 09-02-2013.

- Janssen SA, Vos H, Eisses AR. Hinder door geluid van windturbines: Dosis-effectrelaties op basis van Nederlandse en Zweedse gegevens. Delft: TNO Bouw en Ondergrond. Milieu en Omgeving; 2008 oktober. TNO-rapport 2008-D-R1051/B.

- Janssen SA, Vos H, Eisses AR, Pedersen E. Exposure-response relationships for annoyance by wind turbine noise: a comparison with other stationary sources 2009. Paper presented at Euronoise 2009, Edinburgh, October 2009. Internet: http://hh.diva-portal.org/smash/record.jsf?searchId=1&pid=diva2:332212, accessed 09-02-2013.

- Jervis S. Fall protection consideration in the wind energy industry. Occup Health Saf 2009;78(1):26, 30, 2.

- Jobert A, Laborgne P, Mimler S. Local acceptance of wind energy: Factors of success identified in French and German case studies. Energy Policy 2007;35(5):2751-60.

- Joshi S, Douglas JP, Hamberg A, Teshale S, Cain D, Early-Alberts J. Strategic health impact assessment on wind energy development in Oregon. Portland, OR: Oregon Health Authority; 2012 January 3. Internet: http://www.healthimpactproject.org/resources/body/Oregon-Wind-Energy-HIA_Public-Comment-1-3-12.pdf, accessed 09-02-2013.

- Kaldellis JK, Kapsali M. 2.02 - Wind Energy Contribution in the Planet Energy Balance and Future Prospects. In: Ali S, editor. Comprehensive Renewable Energy. Volume 2: Wind Energy. Oxford: Elsevier; 2012. p. 11-39. Internet: http://www.sciencedirect.com/science/article/pii/B978008087872000202X, accessed 09-02-2013.

- Klæboe R, Turunen-Rise IH, Hårvik L, Madshus C. Vibration in dwellings from road and rail traffic — Part II: exposure–effect relationships based on ordinal logit and logistic regression models. Appl Acoust 2003;64(1):89-109.

- Knopper L, Ollson C. Health effects and wind turbines: A review of the literature. Environ Health 2011;10(1):78.

- Krohn S, Damborg S. On public attitudes towards wind power. Renew Energy 1999;16(1–4):954-60.

- Maguire LA, Lind EA. Public participation in environmental decisions: stakeholders, authorities and procedural justice. Int J Global Environ Issues 2003 3(2):133-48.

- Manwell JF, McGowan JG, Rogers AL. Wind energy explained. Second Edition ed. Chichester, West Sussex, UK: John Wiley and Sons; 2009.

- Maris E, Stallen PJ, Vermunt R, Steensma H. Noise within the social context: Annoyance reduction through fair procedures. J Acoust Soc Am 2007;121(4):2000-10.

- Marsh G. WTs: beaming in on the radar issue. Renew Energy Focus 2007;8(5):36-40.

- Michaud DS, Keith SE, Feder K, Bower T. Health Impacts and Exposure to Wind Turbine Noise: Research Design and Noise Exposure Assessment. Ottawa, Ontario: Health Canada;

2012. Internet: http://www.hc-sc.gc.ca/ewh-semt/consult/_2012/wind_turbine-eoliennes/research_recherche-eng.php, accessed 09-02-2013.

- Miedema HM, Oudshoorn CG. Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals. Environ Health Perspect 2001;109(4):409-16.

- Miedema HM, Vos H. Noise sensitivity and reactions to noise and other environmental conditions. J Acoust Soc Am 2003;113(3):1492-504.

- Miedema HM, Vos H. Noise annoyance from stationary sources: relationships with exposure metric day-evening-night level (DENL) and their confidence intervals. J Acoust Soc Am 2004;116(1):334-43.

- Miedema HME, Vos H. Demographic and attitudinal factors that modify annoyance from transportation noise. J Acoust Soc Am 1999;105(6):3336-44.

- Minister van Klimaat en Energie. Algemene Beleidsnota. Brussel: Belgische Kamer van Volksvertegenwoordigers; 2008. Doc 52 0995/011. Internet: http://www.dekamer.be/FLWB/PDF/52/0995/52K0995011.pdf, accessed 09-02-2013.

- Møller H, Pedersen CS. Hearing at low and infrasonic frequencies. Noise Health 2004;6(23):37-57.

- Møller H, Pedersen CS. Low-frequency noise from large wind turbines. J Acoust Soc Am 2011;129(6):3727-44.

- Morthorst PE. Capacity development and profitability of wind turbines. Energy Policy 1999;27(13):779-87.

- Murray CJL, Acharya AK. Understanding DALYs. J Health Econ 1997;16 703-30.

- Nadaï A. “Planning”, “siting” and the local acceptance of wind power: Some lessons from the French case. Energy Policy 2007;35(5):2715-26.

- Nadaï A, Labussière O. Acceptabilité sociale et planification territoriale, éléments de réflexion à partir de l’éolien et du stockage du CO2. Chapitre 5. In: Ha-Duong M, Chaabane N, editors. Captage et stockage du CO2: Enjeux techniques et sociaux en France. Paris: Quae; 2010. p. 45-60. Internet: http://hal.cirad.fr/docs/00/56/20/42/PDF/Nadai_LabussiA_re_Planification_et_acceptabilitA_sociale_le_cas_de_l_A_olien_en_France_v2.pdf, accessed 09-02-2013.

- NAS-NRC Committee on Environmental Impacts of Wind Energy Projects. Environmental Impacts of Wind-Energy Projects. Washington, DC: The National Academies; 2007. Internet: http://www.nap.edu/catalog.php?record_id=11935, accessed 09-02-2013.

- Nijs W, Lodewijks P, Laes E. Schadekosten van huidige en toekomstige elektriciteitsproductie in Vlaanderen: Schadekosten en inschatting aandeel externe kosten. Mol, België: VITO NV, Unit Transitie Energie en Milieu; 2011 maart. Studie uitgevoerd in opdracht van MIRA, Milieurapport Vlaanderen. Onderzoeksrapport MIRA/2011/02. Internet: http://www.milieurapport.be/nl/publicaties/Onderzoeksrapporten/, accessed 09-02-2013.

- Nordrhein-Westfalen. Erlass für die Planung und Genehmigung von Windenergieanlagen und Hinweise für die Zielsetzung und Anwendung (Windenergie-Erlass) vom 11.07.2011.

Recklinghausen, Deutschland: Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz , Ministerium für Wirtschaft, Energie, Bauen, Wohnen und Verkehr, und Staatskanzlei des Landes Nordrhein - Westfalen; 2011. Internet: http://www.lanuv.nrw.de/geraeusche/windenergie.htm, accessed 09-02-2013.

- OECD. OECD Environmental Outlook to 2050. The consequences of inaction. Paris: Organization for Economic Cooperation and Development, International Energy Agency; 2012 March 15. Internet: http://www.oecd-ilibrary.org/environment/oecd-environmental-outlook-to-2050_9789264122246-en, accessed 09-02-2013.

- Oerlemans S, Schepers JG. Prediction of wind turbine noise and validation against experiment. Amsterdam: National Aerospace Laboratory NLR; 2009. Report NLR-TP-2009-402. Internet: http://reports.nlr.nl:8080/xmlui/handle/10921/244, accessed 09-02-2013.

- Pacco J-F. Gembloux: 1 408 fois non aux éoliennes du Ridias. l'Avenir•net. 2012 avril 14.

- Parsons Brinckerhoff. Update of UK Shadow Flicker Evidence Base. Newcastle upon Tyne, UK: Parsons Brinckerhoff; 2011. Internet: http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/ored_news/ored_news/uk_shad_flick/uk_shad_flick.aspx, accessed 09-02-2013.

- Pasqualetti MJ. Opposing Wind Energy Landscapes: A Search for Common Cause. Ann Assoc Am Geogr 2011;101(4):907-17.

- Passchier-Vermeer W. Vibrations in dwellings: exposure and annoyance. Leiden: TNO Prevention and Health; 1995 December. TNO-report nr 95.058.

- Passchier-Vermeer W, Passchier WF. Noise Exposure and Public Health. Environ Health Perspect 2000;108(Suppl 1):123-31.

- Passchier-Vermeer W, Passchier WF. Environmental noise, annoyance and sleep disturbance. In: Nicolopoulou-Stamati P, Hens L, Howard CV, editors. Environmental Health Impacts of Transport and Mobility. Volume 21; 2005 Environmental Science and Technology Library. p. 25-38.

- Pedersen E, Persson Waye K. Wind turbine noise, annoyance and self-reported health and well-being in different living environments. Occup Environ Med 2007;64(7):480-6.

- Pedersen E, van den Berg F, Bakker R, Bouma J. Response to noise from modern wind farms in The Netherlands. J Acoust Soc Am 2009;126(2):634-43.

- Pedersen E, van den Berg F, Bakker R, Bouma J. Can road traffic mask sound from wind turbines? Response to wind turbine sound at different levels of road traffic sound. Energy Policy 2010;38(5):2520-7.

- Pedersen E, Waye KP. Perception and annoyance due to wind turbine noise--a dose-response relationship. J Acoust Soc Am 2004;116(6):3460-70.

- Pendall R. Opposition to Housing. Urban Aff Rev 1999;35(1):112-36.

- Pepermans Y, Loots I. Wie wind zaait, zal storm oogsten? De sociale aanvaardbaarheid van onshore windenergie. Antwerpen: Universiteit Antwerpen; 2011 november. Internet: http://ir.anet.ua.ac.be/irua/handle/10067/976050151162165141, accessed 09-02-2013.

- Petford N. Meeting society's demand for energy. Chapter 8. In: Harris F, editor. Global environmental issues. 2nd ed. Chichester, West Sussex, England: John Wiley & Sons; 2012. p. 167-200.

- Pierpont N. Wind Turbine Syndrome – A report on a natural experiment. Santa Fe, USA: K-Selected Books; 2009.

- Pohl J, Faul F, Mausfeld R. Belästigung durch periodischen Schattenwurf von Windenergieanlagen. Kiel, Germany: Institut für Psychologie der Christian-Albrechts-Universität; 1999 Juli 31. Internet: http://www.psych.uni-halle.de/abteilungen/sozial/mitarbeiter/pohl/1159230_1304274/, accessed 09-02-2013.

- Pohl J, Faul F, Mausfeld R. Belästigung durch periodischen Schattenwurf von Windenergieanlagen: Laborpilotstudie. Kiel, Germany: Institut für Psychologie der Christian-Albrechts-Universität; 2000 Mai 15. Internet: http://www.psych.uni-halle.de/abteilungen/sozial/mitarbeiter/pohl/1159230_1304274/, accessed 09-02-2013.

- Rabl ARI, Spadaro JV. Environmental Impacts and Costs of Energy. Ann NY Acad Sci 2006;1076(1):516-26.

- RIVM. Nationale Milieuverkenning 5: 2000 - 2030. Alphen aan de Rijn: Samson H.D. Tjeenk Willink bv; 2000. Internet: http://www.pbl.nl/publicaties/2000/Milieuverkenning_5, accessed 09-02-2013.

- Salt AN, Kaltenbach JA. Infrasound From Wind Turbines Could Affect Humans. Bull Sci Technol Soc 2011;31(4):296-302.

- Schreuder DA. De invloed van windturbineparken op de verkeersveiligheid. Leidschendam: Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV; 1992. Rapport R-92-74. Internet: http://www.swov.nl/rapport/R-92-74.pdf, accessed 09-02-2013.

- Smedley ARD, Webb AR, Wilkins AJ. Potential of wind turbines to elicit seizures under various meteorological conditions. Epilepsia 2010;51(7):1146-51.

- Stallen PJM. A theoretical framework for environmental noise annoyance. Noise Health 1999;1(3):69-79.

- Stansfeld SA, Matheson MP. Noise pollution: non-auditory effects on health. British Medical Bulletin 2003;68(1):243-57.

- Stirling A. Limits to the value of external costs. Energy Policy 1997;25(5):517-40.

- Stirling A, Mayer S. Precautionary Approaches to the Appraisal of Risk: A Case Study of a Genetically Modified Crop. Int J Occup Environ Health 2000;6(3):342-57.

- Styles P, Stimpson I, Toon S, England R, Wright M. Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Windfarms. Recommendations on the Siting of Windfarms in the Vicinity of Eskdalemuir, Scotland. Keel, Staffs, UK: School of Physical and Geographical Sciences, Keele University; 2005 July 18. Internet: https://www.wind-watch.org/documents/microseismic-and-infrasound-monitoring-of-low-frequency-noise-and-vibrations-from-windfarms/, accessed 09-02-2013.

- Swofford J, Slattery M. Public attitudes of wind energy in Texas: Local communities in close proximity to wind farms and their effect on decision-making. Energy Policy 2010;38(5):2508-19.

- Tammelin B, Seifert H. Large wind turbines go into cold climate regions. Wilhelmshafen, Germany: Deutsches Windenergie-Institut; 2001. Paper presented at the European Wind Energy Conference 2001, Copenhagen, 2-6 July 2001. Internet: http://www.dewi.de/dewi/fileadmin/pdf/publications/Publikations/seifert_ewec2001_icing.pdf, accessed 09-02-2013.

- Taylor SE, Repetti RL, Seeman T. Health Psychology: What is an Unhealthy Environment and How Does It Get Under the Skin? Annu Rev Psychol 1997;48(1):411-48.

- The Wind Power. Base de données sur les éoliennes et les parc éoliens2012 march. Internet: http://www.thewindpower.net/fiche-pays-21-belgique.php, accessed 09-02-2013.

- Toke D, Breukers S, Wolsink M. Wind power deployment outcomes: How can we account for the differences? Renew Sust Energy Rev 2008;12(4):1129-47.

- Torfs R. Kwantificering van gezondheidsrisico's aan de hand van DALYs en externe gezondheidskosten. Mechelen, België: Vlaamse Milieumaatschappij - MIRA; 2003 april. Studie uitgevoerd in opdracht van de Vlaamse Milieumaatschappij - MIRA, MIRA/2003/02, Vito. Internet: http://www.milieurapport.be/nl/publicaties/Onderzoeksrapporten/, accessed 09-02-2013.

- UK Highways Agency. Wind farm good practice guide. Witham, Essex, UK: Highways Agency; 2007 June 16. Internet: http://webarchive.nationalarchives.gov.uk/20120810121037/http://www.highways.gov.uk/aboutus/documents/CRS_558501_WindFarmGoodPracticeGuide.pdf, accessed 09-02-2013.

- van den Berg F. The effects of wind turbine noise on people. In: Leventhall G, Bowdler D, editors. Wind Turbine Noise: How it is produced, propagated measured and received. Brentwood, Essex, UK: Multi-Science Publishing; 2011.

- van den Berg GP. The sounds of high winds: the effects of atmospheric stability on wind turbine sound and microphone noise [PhD-thesis]. Groningen: Rijksuniversiteit Groningen; 2006.

- van der Horst D. NIMBY or not? Exploring the relevance of location and the politics of voiced opinions in renewable energy siting controversies. Energy Policy 2007;35(5):2705-14.

- Van Hamme E, Loix E. VEA - Draagvlak Windenergie. Heverlee, België: Significant GfK; 2011 februari. Internet: http://www.energiesparen.be/node/880, accessed 09-02-2013.

- van Kamp I. Sociale aspecten van de leefomgeving in relatie tot milieu en gezondheid. Den Haag: Gezondheidsraad; 2012. Rapport 2012/10, achtergrondstudie. Internet: http://www.gezondheidsraad.nl/nl/adviezen/sociale-aspecten-van-de-leefomgeving-relatie-tot-milieu-en-gezondheid, accessed 09-02-2013.

- van Kamp I, Leidelmeijer K, Marsman G, de Hollander AE. Urban environmental quality and human well-being. Towards a conceptual framework and demarcation of concepts; a literature study. Landscape Urban Plan 2003;65(1-2):5-18.

- van Kempen E, van Kamp I, Lebret E, Lammers J, Emmen H, Stansfeld S. Neurobehavioral effects of transportation noise in primary schoolchildren: a cross-sectional study. Environ Health 2010;9(1):25.

- Van Rompaey A, Schmitz S, Kesteloot C, Peeters K, Moens B, Van Hemelrijck H, et al. Landscape capacity and social attitudes towards wind energy projects in Belgium. Brussels: Federal Science Policy (Belspo); 2010. Final report (phase I) SP2223. Internet: http://www.belspo.be/belspo/ssd/science/Reports/LACSAWEP-final%20report-ML.pdf, accessed 09-02-2013.

- Vlaams Minister van Energie, Wonen, Steden en Sociale Economie. Beleidsnota Eenergie 2009-2012. Brussel: Departement Leefmilieu, Natuur en Energie; 2009 november 11. Internet: http://www.vleva.eu/nieuws/beleidsnota-energie-2009-2014-freya-van-den-bossche-vlaams-minister-van-energie-wonen-steden-, accessed 09-02-2013.

- Vlaamse Regering. Titel II van het VLAREM. Besluit van de Vlaamse regering van 1 juni 1995 houdende algemene en sectorale bepalingen inzake milieuhygiëne (B.S. 31 juli 1995). Zoals gewijzigd bij besluiten van de Vlaamse Regering ten laatste per 17 februari 2012. Brussel: Vlaamse Regering; 2012. Internet: http://www.lne.be/themas/vergunningen, accessed 09-02-2013.

- Vorkinn M, Riese H. Environmental Concern in a Local Context: The Significance of Place Attachment. Environ Behav 2001;33(2):249-63.

- WHO-Europe. Night noise guidelines for Europe. Copenhagen: World Health Organization, Regional Office for Europe; 2009. Internet: http://www.euro.who.int/document/e92845.pdf, accessed 09-02-2013.

- WHO. Constitution of the World Health Organization. New York: United Nations; 1946. Basic Documents, Forty-fifth edition, Supplement, October 2006. Internet: http://www.who.int/governance/eb/who_constitution_en.pdf, accessed 09-02-2013.

- WHO. The World Health Organization quality of life assessment (WHOQOL): Position paper from the World Health Organization. Soc Sci Med 1995;41(10):1403-9.

- WHO. Guidelines for Community Noise. Geneva: World Health Organization; 1999. Internet: http://www.who.int/docstore/peh/noise/guidelines2.html, accessed 09-02-2013.

- Wolsink M. Wind power and the NIMBY-myth: institutional capacity and the limited significance of public support. Renew Energy 2000;21(1):49-64.

- Wolsink M. Planning of renewables schemes: Deliberative and fair decision-making on landscape issues instead of reproachful accusations of non-cooperation. Energy Policy 2007a;35(5):2692-704.

- Wolsink M. Wind power implementation: The nature of public attitudes: Equity and fairness instead of 'backyard motives'. Renew Sust Energy Rev 2007b;11(6):1188-207.

- World Bank. Environmental, Health, and Safety Guidelines for Wind Energy. Washington, DC: International Finance Corporation, World Bank Group; 2007 April 30. Environmental, Health and Safety Guidelines. Internet: http://www.docstoc.com/docs/43151115/Environmental-Health-and-Safety-Guidelines-for-Wind-Energy, accessed 09-02-2013.

- World Commission on Environment and Development. Our common future. Oxford, New York: Oxford University Press; 1987.

- Wüstenhagen R, Wolsink M, Bürer MJ. Social acceptance of renewable energy innovation: An introduction to the concept. Energy Policy 2007;35(5):2683-91.

5 ORGANISATIONS CONTACTED

The SHC approached various organisations and public services to provide information about the subject of the present report and to indicate subjects to be considered by the SHC. The following entities were contacted:

Organisations

- Acoustics Engineers ICA, Brussel-Bruxelles
- APERe, Association por la Promotion des Énergies Rénouvelables, Bruxelles
- Bien Vivre à Silly (BIVISI), Comité de défense de l'environnement de la vallée de la Sille
- Bond Beter Leefmilieu, Brussel
- Comité de Défense de l'Environnement de Quiévrain
- Commission consultative communale d'Aménagement du Territoire d'Aubange
- EDORA, Fédération des Producteurs d'Énergies Renouvelables, Bruxelles
- Espace Environnement, Charleroi
- HUB-EHSAL, Centrum voor Duurzaam Ondernemen (CEDON), Brussel
- Inter-Environnement Wallonie, Namur
- ODE, Organisatie Duurzame Energie, Brussel
- VentdeRaison, Gesve
- VWEA, Vlaamse WindEnergie Associatie, Brussel

Administrations and regional governments

- Brussels Instituut voor Milieubeheer - Institut Bruxellois pour la Gestion de l'Environnement, Brussel-Bruxelles
- Cabinet du Ministre de l'Environnement, de l'Aménagement du territoire et de La Mobility, Namur
- Cabinet du Ministre du Développement durable, de la Fonction public, de l'Énergie, du Logement et de la Recherche, Namur
- Conseil supérieur wallon de la Conservation de la nature, Liège
- Institut scientifique de service public, Liège
- Service public de Wallonie, Département de la Nature et des Forêts, Namur
- Service public de Wallonie, Direction de la Prévention des pollutions, Namur
- Vlaams Agentschap Zorg en Gezondheid, Afdeling Toezicht Volksgezondheid, team milieugezondheidszorg, Brussel
- Vlaams Energieagentschap, Interdepartementale Windwerkgroep, Brussel
- Vlaamse overheid, Departement Leefmilieu, Natuur en Energie, Brussel

6 COMPOSITION OF THE WORKING GROUP

All experts joined the working group ***in a private capacity.*** The names of the members and experts of the Superior Health Council are indicated with an asterisk*.

The following experts were involved in drawing up the advice :

▪ BOTTELDOOREN Dick	acoustics	UGent
▪ DEGGOUJ Naïma	ENT, ototoxicity	UCL
▪ FALLON Cathérine	political and social science	ULg
▪ HENS Luc*	human ecology	VUB
▪ NEMERLIN Jean	acoustics	ULg
▪ PASSCHIER Wim*	health risk analysis	Maastricht University
▪ PAULUIS Jean	environmental health	ULg
▪ PEPERMANS Yves	communication science	UA
▪ VAN DEN BERG, Frits	physicist, sound and acoustics	GGD Amsterdam

International peer review :

A draft of the report was reviewed by dr Eric LEBRET affiliated to the National Institute for Public Health and the Environment, Bilthoven, The Netherlands and the Institute for Risk Assessment Sciences of Utrecht University, and by dr Stephen STANSFELD affiliated to the Wolfson Institute of Preventive Medicine of Queen Mary, University of London. Their contribution is gratefully acknowledged.

The working group was chaired by Wim PASSCHIER, the scientific secretaries were Marleen VAN DEN BRANDE and Eric JADOUL.

About the Superior Health Council (SHC)

The Superior Health Council is a federal body that is part of the Federal Public Service Health, Food Chain Safety and Environment. It was founded in 1849 and provides scientific advisory reports on public health issues to the Ministers of Public Health and the Environment, their administration, and a few agencies. These advisory reports are drawn up on request or on the SHC's own initiative. The SHC takes no decisions on the policies to follow, nor does it implement them. It does, however, aim at giving guidance to political decision-makers on public health matters. It does this on the basis of the most recent scientific knowledge

Apart from its 25-member internal secretariat, the Council draws upon a vast network of over 500 experts (university professors, members of scientific institutions), 200 of whom are appointed experts of the Council. These experts meet in multidisciplinary working groups in order to write the advisory reports.

As an official body, the Superior Health Council takes the view that it is of key importance to guarantee that the scientific advisory reports it issues are neutral and impartial. In order to do so, it has provided itself with a structure, rules and procedures with which these requirements can be met efficiently at each stage of the coming into being of the advisory reports. The key stages in the latter process are: 1) the preliminary analysis of the request, 2) the appointing of the experts within the working groups, 3) the implementation of the procedures for managing potential conflicts of interest (based on the declaration of interest, the analysis of possible conflicts of interest, and a referring committee) and 4) the final endorsement of the advisory reports by the Board (ultimate decision-making body). This coherent set of procedures aims at allowing the SHC to issue advisory reports based on the highest level of scientific expertise available whilst maintaining all possible impartiality.

The advisory reports drawn up by the working groups are submitted to the Board. Once they have been endorsed, they are sent to those who requested them as well as to the Minister of Public Health and are subsequently published on the SHC website (www.css-hgr.be), except as regards confidential advisory reports. Some of them are also communicated to the press and to target groups among healthcare professionals.

The SHC is also an active partner in developing the EuSANH network (European Science Advisory Network for Health), which aims at drawing up advisory reports at the European level.

In order to receive notification about the activities and publications of the SHC, you can send a mail to info.hgr-css@health.belgium.be .