Review

Impact of Wind Turbines on Human Health and Safety

Kegel Mateja Aleksandra[1,*], Zerobin Sabine[1,2,3], Suer Mark[1,4,5], Tratnik Janez[1,6], Erd Jakob[5], Jeran Marko[7,*]

1. AAE Gamit, Rečica ob Savinji, Slovenia
2. Energie AG, Linz, Austria
3. Windpower EP GmbH, Parndorf, Austria
4. Exergie GmbH, Vienna, Austria
5. Stromstärke EE GmbH, Vienna, Austria
6. AAE, Maribor, Slovenia
7. "Jožef Stefan" Institute, Department of Inorganic Chemistry and Technology, Ljubljana, Slovenia

* Correspondence: Mateja Aleksandra Kegel, mateja@aae-gamit.si & Jeran Marko, marko.jeran@ijs.si

Citation: Kegel MA, Zerobin S, Suer M, Tratnik J, Erd J, Jeran M. Impact of Wind Turbines on Human Health and Safety. Proceedings of Socratic Lectures. **2025**, 12(II), 60-71. https://doi.org/10.55295/PSL.12.2025.II6

Publisher's Note: UL ZF stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract:
The global challenges of climate change and energy security have highlighted the urgent need for renewable energy solutions, with wind energy making a crucial contribution. As nations strive to reduce greenhouse gas emissions and transition to sustainable energy systems, wind turbines provide a reliable and environmentally friendly alternative to fossil fuels. This article looks at the design, operation and benefits of wind turbines, but also addresses public concerns about noise emissions, infrasound, visual disturbance and electromagnetic fields. While some fears are due to misinformation and psychological factors, modern turbine designs have been shown to mitigate risks and adhere to strict safety standards. In addition, wind energy offers significant health benefits by reducing air pollution and related diseases while promoting economic growth and climate protection. By promoting education and transparent dialogue, wind energy can overcome societal barriers and cement its role in a sustainable and resilient energy future.

Keywords: Wind energy; Renewable energy; Climate change; Health impacts; Noise emissions; Infrasound, Energy security; Sustainable development; Public perception; Wind turbines

1. Introduction

The global challenges of climate change and the ongoing energy crisis have highlighted the urgent need for a transition to sustainable energy systems. As fossil fuel resources dwindle and their environmental impact becomes increasingly severe, the push towards renewable energy has become a cornerstone of international climate and energy strategies. In Europe, initiatives such as the European Green Deal, REPowerEU and the National Energy and Climate Plans (NECPs) set out strategic objectives to tackle these challenges, including reducing greenhouse gas emissions, improving energy security and promoting sustainable economic growth (EU Monitor, 2023).
Among the strategic goals, wind energy has emerged as an important solution. The European Union aims to generate 50% of its energy from wind power by 2050 (**Figure 1**) (Wind Europe, 2024). To achieve this ambitious goal, significant challenges in the areas of energy supply, infrastructure and public acceptance must be overcome. The way to get there is through massive investment in wind energy technologies, grid integration and advances in monitoring and maintenance systems. However, a number of obstacles — including technical, economic, regulatory and social factors — threaten to hinder progress towards this goal (Wind Europe, 2021; Janipur, 2023).

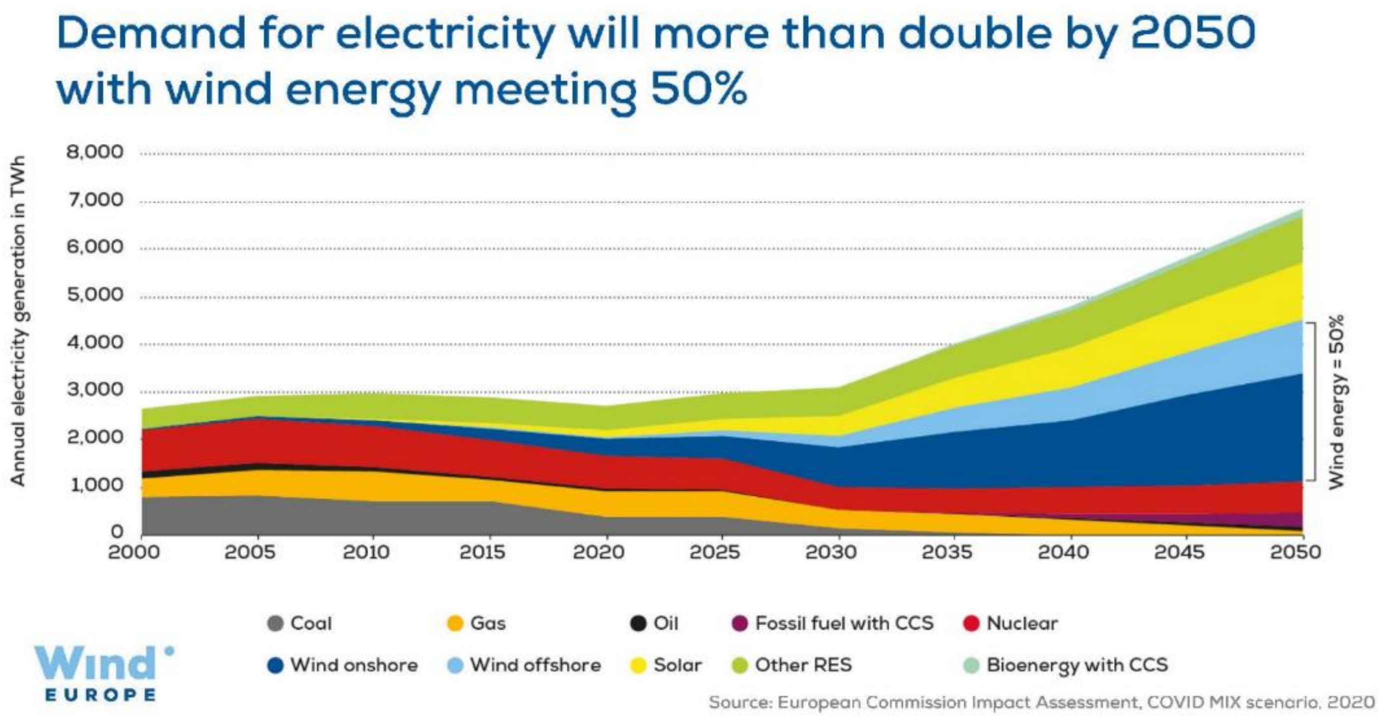

Figure 1. Wind energy meeting 50% by 2050 (*Source*: European Commission Impact Assesment, 2020; *In*: (Wind Europe, 2024)).

One major obstacle is public resistance, often fueled by misinformation and difficulties/problems of understanding about the health and well-being impacts of wind energy (Kegel and Jeran, 2025). Misinformation about visual impacts, noise, shadow flicker and psychological effects such as the nocebo phenomenon have fueled public fears and created barriers to the use of wind energy. These concerns highlight the importance of addressing the technical and social dimensions of wind energy development (Clark, 2022).
This article aims to contribute to a broader understanding of wind energy by examining its role in life monitoring systems and addressing unwarranted public fears based on misinformation. By summarising the current state of knowledge and debunking common myths, the article aims to close knowledge gaps and promote a better-informed public dialogue that supports the EU's vision of a sustainable and resilient energy future (Thyssenkrupp, n. d.).

2. Wind turbines and their characteristics

Understanding the structure, materials and operation of wind turbines is important to understand their role in modern energy systems and address public concerns about their impact. By addressing the mechanics of converting wind to electricity, we can demystify the operation of wind turbines and emphasize their importance as a clean, renewable energy source (U. S. Department of Energy, n. d.). In this section, wind turbines are examined in detail as individual units in a wind farm, focusing on their design, operation and the technologies that ensure their efficiency and safety. A wind turbine converts wind energy into electricity through the aerodynamic forces acting on the rotor blades. Here is a simple explanation of how wind turbines work (U. S. Department of Energy, n. d.).

2.1. Aerodynamics and blade function

The wind flows over the wings and creates a pressure difference on each side. This difference creates lift (stronger force) and drag (weaker force), causing the rotor to turn. The spinning rotor drives a generator directly (direct drive turbines) or via a gearbox, which increases the speed of rotation (U. S. Department of Energy, n. d.). This is the common explanation but there is a more complex flow phenomenon behind it.

2.2. Electricity generation

The generator converts the mechanical energy of the rotor into electrical energy. The copper windings of the generator produce electricity by moving through an (electro)magnetic field (U. S. Department of Energy, n. d.).

2.3. Key components of a turbine

A modern Wind Turbine exists of the following key komponents in different size or small variations (U. S. Department of Energy, n. d.):

- Blades (usually made of fiberglass, they vary in size, with some modern blades being more than 100 meters long)
- hub and rotor (the hub connects the blades to the main shaft; together they form the rotor)
- gearbox or direct drive (increases speed for efficient power generation or connects the rotor directly to the generator in simpler systems)
- governor (starts the turbine at wind speeds of 11–17 km/h and shuts it down at speeds above 88–104 km/h to prevent damage)
- brake (stops the rotor for maintenance).

2.4. Tower and height advantage

Turbines are mounted on towers, often made of tubular steel, concrete and hybrid materials, to capture stronger and steadier winds at greater heights (U. S. Department of Energy, n. d.).

2.5. Pitch and yaw systems

To always achieve the optimum production outcome of the current wind situation, modern Wind Turbines use the following systems to adjust key component’s angles (U. S. Department of Energy, n. d.):

- pitch system (adjusts the angle of the rotor blades to control power production and protects the turbine from too much wind by fogging the rotor blades)
- yaw system (rotates the nacelle – the housing for the turbine's mechanical components – to adjust to the wind direction).

2.6. Electricity transmission

Electricity flows from the generator to a transformer station via transformers that increase the voltage for efficient transmission over long distances. The voltage is then lowered for safe use in homes and businesses (U. S. Department of Energy, n. d.).

2.7. Wind farms

Several turbines are connected together at one location to form a wind farm. These farms generate electricity together and feed it into the grid to supply communities. This process ensures that wind turbines provide clean, renewable energy with minimal environmental impact (U. S. Department of Energy, n. d.).

A detailed understanding of the design and operation of wind turbines reveals the precision and engineering behind these renewable energy systems. By examining their components, functions, and integration into wind farms, it becomes clear how wind turbines are designed to maximize energy production while minimizing environmental and social impact (U. S. Energy Information Administration, 2022).

3. General concerns about health effects

3.1. Noise Emissions from wind turbines

How is sound generated and how does it propagate? Sound is a fluctuation in air pressure that leads to vibrations of the eardrum; sound emissions from a certain source lead to fluctuations in the air particles and thus in the air pressure, and as soon as the fluctuations reach the eardrum, they are audible. Pressure fluctuations cannot only be perceived in the ear but also in other parts of the human body. The frequency of the sound is decisive for perception: the higher the frequency, the more vibrations reach the ear – the sound is perceived as a higher tone, and the unit is hertz (1 hertz is one vibration per second) (**Figure 2**) (IG Windkraft, 2022). Another important unit is sound pressure (intensity), which is measured in decibels (dB). dB corresponds to a logarithmic scale and is preferred to a linear rating scale as it reflects the behavior of the human ear — higher frequencies are perceived as louder than lower frequencies (IG Windkraft, 2022).

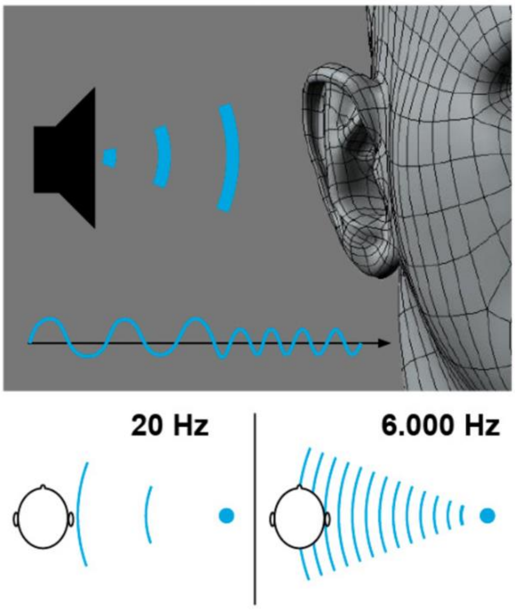

Figure 2. If a person is played a tone of 1,000 Hz, they perceive the volume of this tone as significantly louder than the volume of an actual tone of the same volume (*i.e.* with the same sound pressure) with a frequency of *e.g.* 50 Hz (IG Windkraft, 2022).

3.2. Sound sources in wind turbines and frequency ranges

The dominant source of noise in wind turbines is the rotor blades; the mechanical noise emissions from the gearbox, generator and other auxiliary units play a subordinate role in modern wind turbines and have even been reduced in recent decades (IG Windkraft, 2022). The noise is caused by the interaction of the incoming turbulent wind with the massive rotor blades, which results in a broadband noise with pronounced low-frequency sound pressure levels. The sound pressure level decreases towards higher frequencies (IG Windkraft, 2022).

Another source of noise is the interaction between the blades and the tower, which leads to low-frequency noise (infrasound source) (Oerlemans et al., 2007; Oerlemans, 2009).

Measurements with microphones along the rotor blades have shown that the main source of noise from modern wind turbines is primarily the outer part of the rotor blades, but not directly the tip (**Figure 3**) (Oerlemans et al., 2007).

Figure 3. Location and quantification of noise sources on a wind turbine (Oerlemans et al., 2007).

The measurement also revealed that the noise sources are distributed asymmetrically in the rotor plane, although the blades emit a constant sound pressure level during a complete rotation. The descending blade is perceived louder by an observer on the ground than the ascending blade. This is referred to as a hissing noise (Oerlemans et al., 2007). During one rotation of a three-bladed wind turbine, three different hissing noises can be perceived. For an observer standing directly in front of the wind turbine, the strongest hissing noise occurs at around the 3 o'clock position of the blade (Oerlemans et al., 2007).

3.3. Available methods and technical standards

In the case of wind energy, in addition to emissions directly at the turbine, noise immissions are also important. During the planning phase, the most exposed buildings/neighbourhoods are identified and an immission forecast is carried out (Schlömicher, 2013). The immission forecast is based on the loudest operating state of the turbine. In addition, the previous pollution from other technical systems or operations is taken into account. The immission forecast also takes into account other aspects such as buildings, vegetation or orography, which can influence sound propagation (BWE, 2018). Once the forecast has been completed and the sound levels have been determined, they are compared with specific limit values which may result from federal laws, state laws, technical standards, etc. These laws or standards may also contain instructions for determining sound immissions. For example, the WHO recommends that noise emissions from wind turbines near general residential areas should not exceed a value of 45 dB Lden: The day-evening-night level is a key value for measuring long-term noise exposure. It represents the average sound level over a 24-hour period, with different weighting factors for day, evening and night to take account of people's different sensitivity to noise at different times of the day (European Environment Agency, 2001). During the day (24-hour average of noise emissions) in order to avoid adverse health effects. They do not give recommendations for the night time, but thresholds can be found in several other sources such as the “TA Lärm”, which is the technical set of rules and regulations commonly used in Germany (BWE, 2018).

3.4. Influence of noise emissions from wind turbines on human health

According to van Kamp & van den Berg (2021), a literature search was conducted comprising 12 reviews and 57 original articles (the literature was selected following a

screening of three scientific databases and the selection of publications according to a specific selection procedure which ensured a sufficiently high quality), which was also published in the report *"Health effects related to wind turbine sound: an update"*, National Institute for Public Health and the Environment, 2020 (van Kamp & van den Berg, 2020). According to this research noise from wind turbines is low compared to other sources such as traffic (road, rail and air) or industry and is generally below 45 dB (van Kamp & van den Berg, 2021). Nevertheless, the noise from wind turbines is perceived as more disturbing than that from many other sources with the same sound level. Living near a wind turbine or listening to wind turbines can lead to chronic annoyance for residents. For other health effects such as sleep disturbances, insomnia or effects on mental health, the evidence is contradictory or insufficient. There is no evidence that the low-frequency component affects residents in any other way than the typical sound or that infrasound, which is far below the hearing threshold, can have an impact. The level and amplitude modulation of all wind turbine noise are the main causes of increased annoyance, not low-frequency sound or infrasound (van Kamp & van den Berg, 2021).
Although low-frequency noise emissions cannot be heard, they may still lead to annoyance, but the link between wind turbines and low-frequency noise has not been established. The causality and directionality of these effects remain unproven (McKenna at al., 2025).

3.5. What is infrasound?

Infrasound is an everyday phenomenon. It is in general sound with a frequency below 20 Hz (Ratzel et al., 2016). Almost every sound emission also contains infrasound components – the decisive factor is the intensity. In wind turbines the infrasound is generated during rotation: The rotor blades generate turbulent air flow and when the rotor blade passes the tower this turbulent flow is interrupted resulting in infrasound. For many sound sources such as traffic, wind itself, compressors (of refrigerators), motors, etc., the infrasound is more intense than for wind turbines. A comparison between a wind turbine and a car (inside with back windows open and with all windows open) is shown in **Figure 4**, where the intensity of infrasound emissions of the car is significantly higher than the intensity of the wind turbine. Also, the infrasound emitted by wind turbines is lower than the perception treshold (Fachagentur wind und solar, n. d).

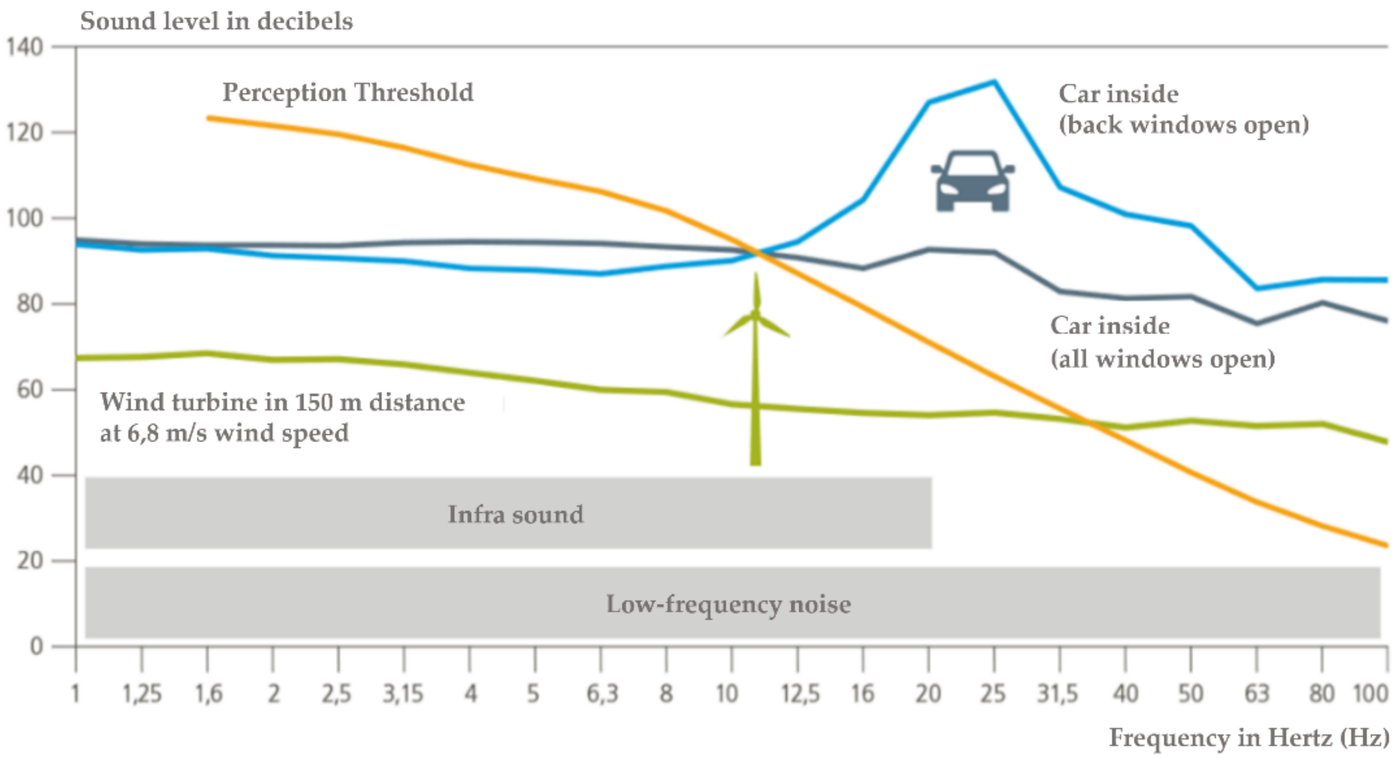

Figure 4. The other sound sources (car etc., are significantly louder than the wind turbine as a sound source (Fachagentur wind und solar, n. d)).

3.6. Electromagnetic fields (EMFs): How are they generated?

EMFs are made up of magnetic and electric fields. They are created when electrical voltages and currents change, causing an electromagnetic wave to propagate spatially.
EMFs can be generated in nature or in technical devices and systems, *e.g.* in televisions, hair dryers or wind turbines. They can be characterized by their frequency, measured in Hertz (Hz), and their magnetic flux density, measured in milliGauss or Tesla (mG or T). Various sensors, such as Hall sensors, are available for measuring the EMF (McCallum et al., 2014).
Influence on human health and effect of EMF in wind turbines on people living near the wind farm. Several publications show that EMFs are only detectable in the immediate vicinity of wind turbines. In the study *"Measuring electromagnetic fields (EMF) around wind turbines in Canada: is there a human health concern?«* by McCallum et al. (2014), measurements of electromagnetic fields (EMF) were carried out and the authors found that the EMF could no longer be distinguished from the background within 2 m of the base.
EMF levels measured within 2 to 3 m of the wind turbines were comparable to or lower than magnetic field measurements near typical household electrical appliances (**Figure 5**) (Knopper et al., 2014).

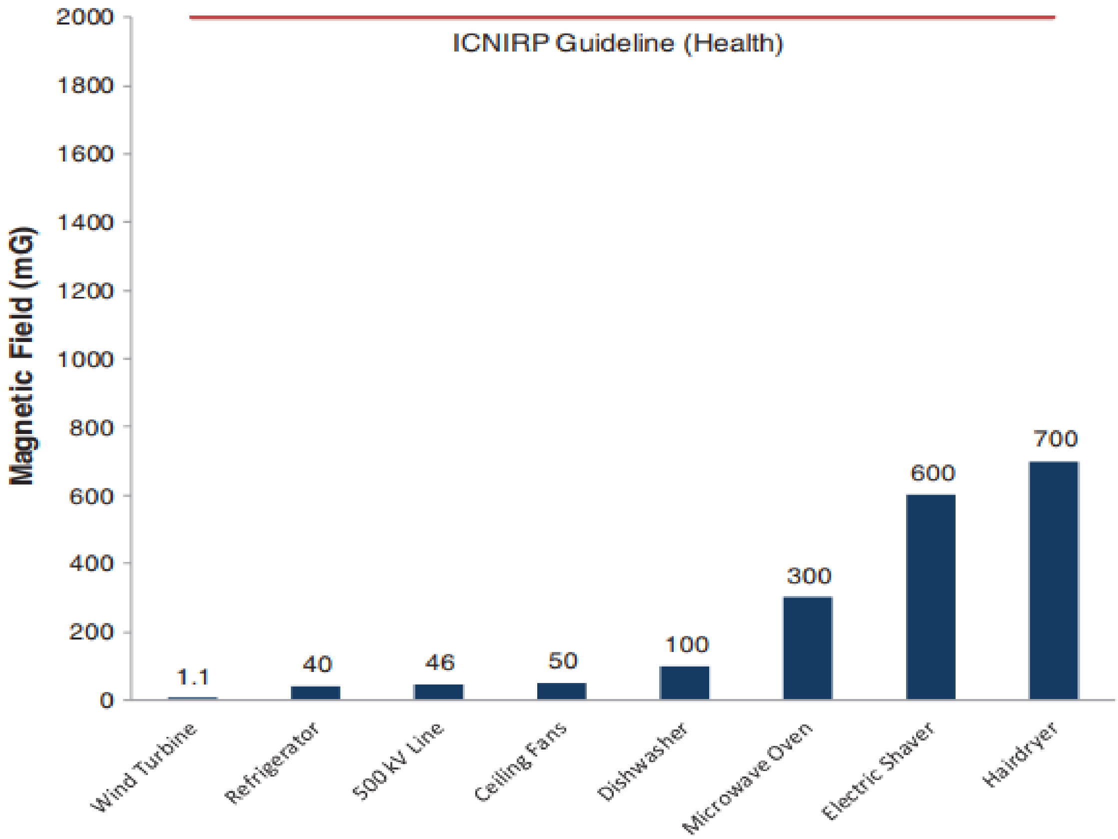

Figure 5. The picture shows that the EMFs are located significantly below the threshold given by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (Knopper et al., 2014).

4. Visual & psychological effects of wind farms

Wind turbines' visual and psychological impacts have been the subject of various scientific studies.

4.1. Visual impacts

Research, including seventeen primary studies on health effects due to visual characteristics of wind turbines, found no evidence of serious adverse health effects reported for visual exposures. Most studies primarily investigated the frequency of annoyance to residents living up to 1200 m from the nearest wind turbine (Meyer, 2022). Depending on the type of visual exposure (*e.g.* shadow flicker, reflection) the prevalence of annoyance varied between 7 and 31% (Meyer, 2022). The pooled prevalence of high annoyance was the same for shadow flicker and altered visibility from wind turbines (6%) (Freiberg, 2019). If there is a possibility that impacts from shadow flicker may occur, mitigation measures can minimize or eliminate these impacts. Shadow flicker impacts can be reduced either by optimizing the placement of WTGs, by screening the line of sight between receptors and problematic WTGs (*e.g.* through landscaping), or by restricting the operation of WTGs during the critical periods when shadow flicker impacts are most likely to occur (Meyer, 2022).

4.2. Psychological effects & nocebo effects

The nocebo effect is also a psychological phenomenon in which negative expectations of a particular stimulus or situation lead to the perception of negative effects, even if there is no direct physical cause. In the context of wind turbines, this effect has been studied in detail to understand why some people report health complaints in the vicinity of wind farms, even though there is no conclusive evidence that wind turbines cause direct damage to health (Crichton et al., 2014).

"Wind turbine syndrome" refers to symptoms reported by people living near wind farms. These symptoms include headaches, dizziness, nausea, sleep disturbances, anxiety and other non-specific complaints. Studies such as the one published in *Noise & Health* in 2014 (Rubin et al., 2014), suggest that these symptoms are not directly caused by physical aspects of wind turbines (*e.g.* noise or infrasound), but may be related to the nocebo effect, where the belief that wind turbines are harmful produces actual physiological or psychological discomfort (Rubin et al., 2014).

4.3. Physical safety and health risks

Although wind turbines are generally safe and meet stringent safety standards, potential risks such as ice throw, mechanical failure and fire hazards are occasionally identified. Ice throw occurs when ice accumulates on the turbine blades in cold conditions and detaches during rotation, which can pose a localized safety hazard. However, modern turbine designs have advanced monitoring systems that detect and mitigate such conditions, significantly reducing the likelihood of accidents. Rare mechanical failures, including blade fractures, are also cited as a risk (Rubin et al., 2014). However, due to strict safety protocols, regular maintenance schedules and advanced engineering designs, these events are extremely rare. Wind turbines must comply with international safety standards while minimizing risks to the surrounding environment. In addition, potential fire risks are mitigated by fire-resistant materials and monitoring systems. Modern wind farms have advanced fire protection systems, including heat sensors, automatic fire extinguishing systems and fire-retardant coatings (Rubin et al., 2014). Detailed risk assessments are carried out prior to construction, including analyzing the potential for ignition and developing appropriate countermeasures. Wind farms in cold climates have de-icing technologies such as heating elements on the rotor blades or coating systems with substances that prevent ice formation. The use of these technologies significantly reduces the risk of ice drift. In areas with low temperatures, safety markings are used and protection zones are set up to protect people and property. Studies show that the risk of injury is extremely low if these measures are observed. Wind farms are designed with local weather conditions in mind and built to withstand extremely strong winds and other weather extremes. For example, the construction may be made of robust materials that are resistant to vibrations and weather influences. Studies show that the vibrations emitted by wind farms have no significant impact on surrounding properties or buildings. Modern turbines use vibration damping technologies to ensure stability and minimal impact on the surrounding area (Rubin et al., 2014).

5. Positive effects of wind energy on human health and beyond

Wind energy is one of the healthiest energy sources available today. Its use offers numerous health and environmental benefits, making it a key component of the transition to sustainable energy systems. Wind energy offers a sustainable and renewable energy solution and significant health benefits by reducing pollution, lowering healthcare costs, promoting community development and contributing to global ecological well-being (Local Government Association, n. d.).

5.1. The elimination of greenhouse gas emissions

Burning fossil fuels is one of the main causes of global warming, while renewable energy generates electricity without emitting carbon dioxide or other pollutants. According to the International Renewable Energy Agency (IRENA, 2022), switching to renewable energy could reduce carbon dioxide emissions by up to 70% by 2050, underlining its crucial role in combating climate change (IRENA, 2022). Unlike fossil fuels, wind turbines generate electricity without emitting greenhouse gasses. This freedom from emissions is crucial, as burning fossil fuels releases toxic and carcinogenic substances into the atmosphere that contribute to serious health problems. In the United States, for example, coal pollution is linked to around 50,000 premature deaths each year (IRENA, 2022).

5.2. Reducing health costs

The pollutants produced by coal-fired power plants have significant health impacts and lead to considerable economic burdens. In Australia, the cost of the health impacts of this pollution is estimated at AUD 2.6 billion per year (Biegler, 2009). Switching to wind energy can reduce these health risks and associated costs by providing a cleaner alternative (Climate Council, 2015).

5.3. Promoting the wellbeing of rural communities

Wind energy projects often provide economic opportunities for rural areas. Wind farm development can boost local economies through job creation and infrastructure investment. In addition, renewable energy initiatives empower rural communities to become self-sufficient in energy and reduce dependence on fossil fuels (Ionescu, 2024).

5.4. Ccontribution to global environmental health

The use of wind energy reduces carbon emissions, which plays an important role in combating climate change. Stabilizing the climate is crucial to prevent the escalation of extreme weather events and protect ecosystems. The use of renewable energy sources such as wind energy is a proactive step towards securing the long-term health of our planet (Local Government Association, n. d.).

5.5. Confirmation of safety by health authorities

Extensive reviews by health organizations have found no consistent evidence of a link between wind farms and adverse effects on human health. For example, the Australian government's National Health and Medical Research Council concluded that wind turbines pose no health risks, underscoring the safety of wind energy as an energy source. (Climate Council, 2015).

5.6. *Energy security: using renewable energy sources for a more stable and cleaner energy supply*

Energy security has become a cornerstone of sustainable development, with renewable energy sources playing a central role in creating a reliable, clean and resilient energy system. Traditional energy systems that rely heavily on fossil fuels are vulnerable to price volatility, geopolitical conflict and resource depletion. Renewable energy sources mitigate these risks by enabling localized and diversified energy production. For example, solar and wind power plants can be deployed in different regions, reducing dependence on centralized, disruption-prone energy grids (IRENA, 2022). This decentralized approach increases the resilience of grids and ensures the availability of energy even in times of crisis. In addition, renewable energy technologies are not subject to the same supply chain constraints as fossil fuels. Unlike coal, oil or natural gas, which have to be extracted and transported over long distances, renewables use inexhaustible resources such as sunlight and wind. This inherent stability enables countries to achieve greater energy independence and become less dependent on external market fluctuations. (IRENA, 2022).

5.7. Social acceptance of wind energy

The study *"Social acceptance of wind energy in urban landscapes"* by Westerlund (2020) examines the factors that influence the social acceptance of wind energy in urban environments. It highlights that positive perceptions are often associated with increased awareness and understanding of the benefits of wind energy, suggesting that educational initiatives can improve acceptance. The main findings are that there are different types of acceptance: Protagonists are highly supportive of urban wind energy projects; centrists are neutral or ambivalent towards such projects; and antagonists are opposed to the introduction of wind energy in urban areas (Westerlund, 2020). An important finding for project developers and political decision-makers is that active participation of the population in planning and decision-making can increase acceptance. Considering optimal distances from residential areas can also allay concerns about proximity. Tailored information and participation strategies for different demographic groups, *e.g.* by gender, can improve public awareness and support (Westerlund, 2020).

6. Conclusion

Wind turbines are one of the cornerstones of the global transition to sustainable energy systems and offer numerous environmental, economic and health benefits. While concerns have been raised about noise emissions, infrasound, ice throw and visual impacts, evidence shows that these issues are either negligible or effectively mitigated by modern technologies and stringent safety standards. Misinformation and psychological factors, such as the nocebo effect, often contribute to public concern and emphasise the need for education and transparent communication.

The health benefits of wind energy, such as the reduction of air pollution and associated diseases, far outweigh the potential risks. In addition, wind energy contributes to energy security, job creation and climate change mitigation, making it an indispensable element of a sustainable and resilient energy future. By removing technical, legal and social barriers and promoting an informed public dialogue, the potential of wind energy can be fully realised in line with global efforts to combat climate change and protect public health.

This article aims to contribute to a broader understanding of wind energy, make sense of the often misunderstood theories of health impacts, and highlight the benefits of wind energy for policy makers and individuals, that can also contribute to stress reduction.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Biegler T."The hidden costs of electricity: Externalities of power generation in Australia"; Australian Academy of Technological Sciences and Engineering. 2009. Available at: https://apo.org.au/sites/default/files/resource-files/2009-02/apo-nid4196.pdf. Access at 02.02.2025
2. Bundesverband WindEnergie, 2022. "Schall (*Engl*. Sound)". Available at: https://www.wind-energie.de/themen/mensch-und-umwelt/schall/. Access at 02.02.2025
3. BWE, 2018. "Schallimissionen von Windkraftanlagen (*Engl*. Noise emissions from wind turbines)". Available at: https://www.wind-energie.de/fileadmin/redaktion/dokumente/publikationen-oeffentlich/themen/01-mensch-und-umwelt/05-schall/20181123_BWE_Informationspapier_Schall_und_WEA.pdf. Access on: 02.02.2025
4. Clark H, 2022. "Wind turbines and public health." Available at : https://cleanpower.org/wp-content/uploads/gateway/2022/11/ACP_Wind-Turbines-and-Health-Fact-Sheet_8.24.pdf. Access on: 02.02.2025
5. Climate Council, 2015. "Five reasons why wind power is one of the healthiest forms of energy". Available at: https://www.climatecouncil.org.au/five-reasons-why-wind-power-is-one-of-the-healthiest-forms-of-energy/. Access on: 02.02.2025
6. Crichton F, Chapman S, Cundy T, Petrie KJ. The link between health complaints and wind turbines: Support for the nocebo expectations hypothesis. Front. Public Health. 2014; 2: 220. DOI: https://doi.org/10.3389/fpubh.2014.00220

7. EU Monitor, 2023. “Explanatory Memorandum to COM(2023)796 – EU wide assessment of the draft updated National Energy and Climate Plans An important step towards the more ambitious 2030 energy and climate objectives under the European Green Deal and RePowerEU”. Available at: https://www.eumonitor.eu/9353000/1/j4nvhdfdk3hydzq_j9vvik7m1c3gyxp/vm94l1abq8u6. Access on: 02.02.2025
8. European Environment Agency, 2001. “Term: Lden”. Available at: https://www.eea.europa.eu/help/glossary/eea-glossary/lden
9. Fachagentur wind und solar, n. d. “Infraschall und windenergieanlagen (*Engl*. Infrasound and wind turbines). Availableat: https://www.fachagentur-windenergie.de/themen/schallimmissionen/infraschall-und-windenergieanlagen/. Access on: 02.02.2025
10. Freiberg A, Schefter C, Hegewald J, Seidler A. The influence of wind turbine visibility on the health of local residents: A systematic review. Int Arch Occup Environ Health. 2019; 92: 609-628. https://doi.org/10.1007/s00420-019-01403-w
11. IG WindKraft, 2022. “Windenergie und infraschall (*Engl*. Wind energy and infrasound)”. Available on: https://www.igwindkraft.at/fakten/?xmlval_ID_KEY[0]=1261. Access at 02.02.2025
12. Ionescu D, 2024. “Rural areas benefiting from wind energy revenue”; Planetizen. Available at: https://www.planetizen.com/news/2024/07/130543-rural-areas-benefiting-wind-energy-revenue. Access on: 02.02.2025
13. IRENA, 2022. “World energy transitions outlook 2022: 1.5 °C pathway”. Available at: https://www.irena.org/publications/2022/mar/world-energy-transitions-outlook-2022. Access on: 02.02.2025
14. Janipur Z, 2023. “Research: The bottlenecks challenging growth in the EU offshore wind supply chain”. Available at:https://www.rabobank.com/knowledge/d011354306-the-bottlenecks-challenging-growth-in-the-eu-offshore-wind-supply-chain. Access on: 02.02.2025
15. Kegel MA, Jeran M. On the way to renewable energy sources: Wind energy and wind farm, 2025. *Poster*: Submitted in the Symposium of the Socratic Lectures.
16. Knopper LD, Ollson CA, McCallum LC, Whitfield Aslund ML, Berger RG, Souweine K, McDaniel M. Wind turbines and human health. Front. Public Health. 2014; 2: 63. DOI: https://doi.org/10.3389/fpubh.2014.00063
17. Local Government Association, n. d. “Benefits and potential impacts of wind energy”. Available at: https://www.local.gov.uk/benefits-and-potential-impacts-wind-energy. Access on: 02.02.2025
18. McCallum LC, Whitfield Aslund ML, Knopper LD, Ferguson GM, Ollson AC. Measuring electromagnetic fields (EMF) around wind turbines in Canada: Is there a human health concern?. Environmental Health. 2014; 13: 92014. DOI: https://doi.org/10.1186/1476-069X-13-9
19. McKenna R, Lilliestam J, Heinrich HU, Weinand J, Schmidt J, Staffell I, at al. System impacts of wind energy developments: Key research challenges and opportunities. Joule. 2025; 9: 101799. DOI: https://doi.org/10.1016/j.joule.2024.11.016
20. Meyer A, 2022. “Wind turbines and shadow flicker impacts”; WKC Group. Availabe at: https://www.wkcgroup.com/news/wind-turbines-and-shadow-flicker-impacts. Access on: 02.02.2025
21. Oerlemans S, 2009. “Detection of aeroacoustic sound sources on aircraft and wind turbines”, Thesis, University of Twente, Zwolle, The Netherlands. Available on: https://ris.utwente.nl/ws/portalfiles/portal/6119338/thesis_S_Oerlemans.pdf
22. Oerlemans S, Sijtsma P, Mendez-Lopez B, 2007. “Location and quanticifaction of noise sources on a wind turbine”, National Aerospace Laboratory NLR. Available at: https://reports.nlr.nl/server/api/core/bitstreams/bf58b595-a352-49f8-84e6-5b6bfac44839/content . Access on: 02.02.2025
23. Ratzel U, Bayer O, Brachat P, Hoffmann M, Jänke K, Kiesel KJ, Mehnert C, Scheck C; Landesanstalt für Umwelt Baden-Württemberg, 2016. “Low-frequency noise including infrasound from wind turbines and other sources”. Availabe at: https://www.igwindkraft.at/mmedia/download/2024.07.10/1720618693326744.pdf. Access on: 02.02.2025
24. Rubin GJ, Burns M, Wessely S. Possible psychological mechanisms for "wind turbine syndrome". On the windmills of your mind. Noise Health. 2014; 16: 116-22. DOI: 10.4103/1463-1741.132099
25. Schlömicher T, 2013. “Aeroacoustic noise prediction of horizontal axis wind turbines”, Master thesis, Graz University of Technology. Availabe from: https://diglib.tugraz.at/aeroacoustic-noise-prediction-of-horizontal-axis-wind-turbines-2013
26. Thyssenkrupp, n. d. “Reality check – Debunking six myths about wind energy”. Available at: https://www.thyssenkrupp.com/en/stories/sustainability-and-climate-protection/reality-check-debunking-six-myths-about-wind-energy. Access on: 02.02.2025
27. U. S. Department of Energy, n. d. “How a wind turbine works – Text version”. Available at: https://www.energy.gov/eere/wind/how-wind-turbine-works-text-version. Access on: 02.02.2025
28. U. S. Energy Information Administration, 2022. “Wind is an emissions-free soure of energy”. Available at: https://www.eia.gov/energyexplained/wind/wind-energy-and-the-environment.php. Access on: 02.02.2025

29. Van Kamp I, van den Berg F. Health effects related to wind turbine sound: An update. Int J Environ Res Public Health. 2021; 18: 9133. DOI: https://doi.org/10.3390/ijerph18179133
30. Van Kamp I, van den Berg GP, 2020. "Health effects related to wind turbine sound: an update"; RIVM report 2020-0150, Bilthoven, The Netherlands. Available on: https://www.rivm.nl/bibliotheek/rapporten/2020-0150.pdf DOI: https://doi.org/10.21945/RIVM-2020-0150
31. Westerlund M. Social acceptance of wind energy in urban landscapes. Technol Innov Manag Rev. 2020; 10: 49-62. DOI: http://doi.org/10.22215/timreview/1389
32. Wind Europe, 2021. "Getting fit for 55 and set for 2050". Available at: https://windeurope.org/intelligence-platform/product/getting-fit-for-55-and-set-for-2050/
33. Wind Europe, 2024. "Wind energy facts and figures". Available at: https://windeurope.org/intelligence-platform/product/wind-energy-facts-and-figures/. Access on: 02.02.2025