# HUMAN HEALTH

## *What you should know:*

- Climate change poses a significant risk to human health by changing weather patterns and leading to more severe storms, flooding, droughts, and heat waves. Greenhouse gas (GHG) emissions from the electricity sector are the single largest contributor to climate change.
- Onshore and offshore wind and solar power technologies not only reduce carbon emissions from power production systems, but also reduce human health impacts from air pollution and environmental toxicity associated with the combustion of fossil fuels.
- Air emissions related to offshore wind are primarily associated with the manufacturing phase of the wind turbines and their magnitude is driven by the sources of electricity at the manufacturing location. However, over its lifetime, offshore wind projects showcase the potential for significant decarbonization and emission reduction – reducing emissions by approximately 108 times compared to traditional fuel sources, for the same amount of electricity produced.
- Exposure to electromagnetic fields (EMFs) from both offshore cables and onshore cable landings, substations, and transmission associated with offshore wind, is limited and well within safety and health guidelines established by the International Committee on Electromagnetic Safety (ICES) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

## *Spotlight Question: Are EMFs from offshore wind cables harmful to human health?*

Overall, research has not shown that long-term exposure to low-level, low-frequency electromagnetic fields (EMFs) emitted by offshore wind cables has detrimental effects on human health (International Commission on Non-Ionizing Radiation Protection [ICNIRP], n.d.).

EMFs are invisible areas of electrical and magnetic energy that are associated with electrical power and various forms of natural and anthropogenic lighting. EMFs are produced by the movement of electric charges through a conductor and can be present in the marine environment from both natural and anthropogenic sources.

The most common naturally occurring direct current (DC) field in the marine environment is the Earth's 0-Hz geomagnetic field, while alternating current (AC) fields that occur at frequencies of less than 10 Hz are naturally produced by marine organisms. Undersea telecommunications and power cables on the ocean floor, which form the critical infrastructure for modern day internet connectivity and power distribution, also generate AC and DC EMFs.

For offshore wind energy, human exposure to EMF is mostly limited to the onshore cable landing points, substation, and existing transmission networks. High-voltage direct current (HVDC) lines are used to transport large amounts of energy over long distances through land or sea. The operation of these lines produces static electric fields (EF). Petri et al. (2017) conducted a systematic review on the biological effects of static EFs from HVDC transmission on humans and other vertebrates and concluded that the weight of evidence from the literature reviewed did not indicate that static EFs have adverse biological effects on humans or other animals. A review performed for the National Radiation Protection Board (NRPB) in the United Kingdom evaluated 11 studies on the biological effects of static EF and concluded that the experimental studies available did not provide evidence of adverse effects on human health (Petri et. al, 2017).

The magnetic field one meter from an HVDC line is no stronger than the Earth's magnetic field. HVDC submarine cables produce DC magnetic fields much smaller than thresholds where physiological impacts would occur and direct human exposure to DC magnetic fields from HVDC submarine cables is highly unlikely. Physiological responses have been observed in medical test cases in the presence of a magnetic field, but only for a field nearly 100,000 times this strength (Figueroa-Acevedo et al., 2015). Thus, magnetic fields from offshore wind cables will likely have no adverse effects on human health.

## Climate Change & Human Health

The energy sector has long relied on the burning of fossil fuels to produce energy, but renewable energy sources, such as wind power, offer an alternative form of energy production without the consequence of greenhouse gas (GHG) emissions. Burning, refining, and extracting fossil fuels for energy releases carbon dioxide ($CO_2$) and other gases into the atmosphere, which had previously been locked up in the form of coal, oil, and subsurface natural gas. $CO_2$ is a greenhouse gas that traps heat in the atmosphere. The observed increases in greenhouse gases in the atmosphere are unequivocally caused by human activity, with the largest contributor being the combustion of fossil fuels (Intergovernmental Panel on Climate Change [IPCC], 2023). With the exponential increase in global $CO_2$ levels in the atmosphere over the past century, there has been a documented increase in global sea-surface, air, and atmospheric temperatures (Humlum et al., 2013). To date, global temperatures have risen roughly 2° F (1°C) since pre-industrial times (Lindsey & Dahlman, 2024). Changes in weather patterns linked to this increase in temperature include:

- regional and seasonal temperature extremes (Lindsey & Dahlman, 2024);
- increased storm intensities and prolonged hurricane seasons (Buis, 2020);
- reduced snow and polar ice cover (Vihma, 2014; Lindsey & Dahlman, 2024);
- sea-level rise (Alley et al., 2005); and
- more erratic precipitation patterns leading to floods and droughts (Lindsey & Dahlman, 2024; U.S. Geological Survey [USGS], 2022).

Human health is negatively impacted by climate change in a variety of ways. A warming climate has been found to lead to increased risk of mortality. The risk of mortality was calculated to increase by 0.1% to 1.1% per 1°C of warming (Cromar et al., 2022). According to the World Health Organization (WHO), heatwaves killed more than 166,000 people from 1998 to 2017, with the 2003 European heatwave alone responsible for a staggering death toll of 70,000 (WHO, 2020). The number of people exposed to heatwaves has increased by 125 million between 2000 to 2016 (WHO, 2020) and with heatwave temperatures setting global records in 2023 (Hersher, 2023) this number is likely to increase. As a result, more people utilize air conditioning to cool down, which in turn, increases the demand for energy in a feedback loop that exacerbates the problem. Erratic weather patterns and intensifying droughts can also limit reliable access to clean water and pose major threats to agricultural stability (USGS, 2018; USGS, 2024). Further, 70% of refugees and 80% of internally displaced people originate from countries on the front lines of the climate crisis. These countries are climate "hotspots" where climate impacts are more significant and local governments typically lack the resources to adapt to an increasingly inhospitable environment. The cumulative damages caused by climate change on economies can be quantified into a value known as the "Social Cost of Carbon Dioxide" (SC-$CO_2$). A recent study calculated the SC-$CO_2$ for the year 2022 was estimated to be $185 per ton of $CO_2$ (Rennert et al., 2022).
The energy industry is by far the largest contributor to global $CO_2$ emissions, accounting for roughly 38% of global emissions in 2021 (Statista, 2021). Therefore, replacing carbon emitting fossil fuel-based power with renewable energy sources, such as solar and wind technologies, would make a significant contribution toward

reducing GHG emissions and minimize the associated human health impacts from climate change. To read more about the effects of climate change on human health visit Climate Change.

## Offshore Wind Sources of Potential Human Health Effects

### Onshore Noise and Traffic

The Noise Control Act of 1972 authorized U.S. federal agencies to adequately control noise that may endanger the health and welfare of the nation's population. In 1974, the U.S. Environmental Protection Agency (EPA) conducted a study on noise impacts relative to public health and safety (EPA, 1974) and developed noise limits to protect public health and welfare regarding potential interference with outdoor and indoor activities (Table 1). This EPA study provides guidance on the potential effects of noise that can be considered by federal, state, and local agencies, but does not constitute a standard or regulation. Further, states may adopt their own quantitative noise limits for operations of wind turbines or defer to municipalities to establish and enforce noise limits (VHB, 2020).

**Table 1: EPA Noise Level Thresholds**

EPA Noise Levels Identified to Protect Public Health and Welfare

| Effect | Level | Area |
|---|---|---|
| Outdoor Activity Interference | LDN [55 dBA] | Outdoors in residential areas and farms, other outdoor areas where people spend widely varying amounts of time, and other places in which quiet is a basis for use |
| | LEQ(24) [55 dBA] | Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, parks, etc. |
| Indoor Activity Interference and Annoyance | LDN [45 dBA] | Indoor residential areas |
| | LEQ(24) [45 dBA] | Other areas with human activities, such as schools |

Source: EPA, 1974.

Table Notes:
1) A decibel (dB) is a unit of measurement for sound. A-weighted decibels, abbreviated dBA, are an expression of the relative loudness of sounds in air as perceived by human ears. Sounds at or below 70 dB are generally safe while sounds above 70 dB for a prolonged exposure can harm human hearing.
2) The day-night average sound level (Ldn or DNL) is the average noise level over a 24-hour period and is a metric used to reflect a person's cumulative exposure to sound over a 24-hour period.
3) The equivalent sound level (LEQ) measures the average acoustic energy over a period of time to take account of the cumulative effect of multiple noise events. For example, this is a measure of the aggregate sound at a location that has airplane flyovers throughout the day.

During the construction and installation of offshore wind turbines, noise levels can be produced by vessel or vehicle traffic and installation activities, such as pile driving and cable installation (Tethys, n.d.). Offshore construction activities will include vessels and helicopters to transport materials and people to and from the project sites. In addition, the pile driving of offshore wind turbine foundations and substations installation into the seabed during construction generates underwater noise pollution, which is of primary environmental concern. Pile driving noise is modeled in detail and evaluated for mitigation needs as part of the project's permitting process. Operation of offshore wind turbines may also produce low levels of noise from the rotation of turbine blades, movement of floating devices on the surface, or strumming of mooring lines and cables (Tethys, n.d.). To learn more about noise impacts, visit Marine Mammals and Sea Turtles or Fish and Invertebrates.

#### Pile Driving

Using the project estimations of the Revolution Wind Farm project in Rhode Island/Connecticut as an example, noise intensity from pile driving is expected to register at 11.2 dBA (see Table 1 Notes for description) or less at the nearest shorelines (VHB, 2020), which is three to four times lower than the EPA guidance levels for Outdoor Activity Interference. At these low levels, sound from pile driving activities is not likely to be audible at shorelines.

#### Offshore Cable Installation

In general, the installation of offshore wind export cables is expected to progress at a rate of approximately 200 to 800 meters per hour (VHB, 2020). Therefore, installation vessels are unlikely to be near a particular onshore area for an extended period of time and no significant onshore noise effects are anticipated.

#### Cable Landfall Construction

Horizontal directional drilling (HDD) may be used in some cases to connect the offshore export cables to an onshore substation. Construction activities would include site preparation for HDD activities, such as pile driving a sheet pile anchor wall. Overall construction sound levels for the range of activities evaluated for Revolution Wind, for example, would be between 51 and 70 dBA (LEQ (8h)- average noise level for an eight-hour period) at the nearest beach and between 14 and 51 dBA (LEQ (8h)) at the nearest residential structures (VHB, 2023). These sound levels for construction activities and HDD operations would comply with relevant state and local noise limits for all daytime construction activities and are not expected to cause significant adverse noise impacts. To learn more about HDD, visit Coastal and Marine Habitats.

#### Onshore Infrastructure Construction

Construction of the onshore transmission cable involves different phases, such as clearing the transmission cable route, excavation of the route, support of excavation with shoring, installation of the duct, and backfill and final restorative activities. Construction activities associated with an onshore substation and interconnection facility can include clearing the site of vegetation, grading the site, installing erosion controls, construction of buildings, and restoration of any disturbed areas. Construction sound during the day could be up to 10 to 15 dBA above ambient conditions, which vary locally (VHB, 2023). Construction of the onshore substation and interconnection facility would occur during daytime hours and would adhere to all applicable state and local noise standards.

#### Onshore Substation Operations

Based on the model results, operational sound from onshore substations would be below the nighttime noise ordinance limit for residential properties (50 dBA). In addition, sound from onshore substations would measure below 50 dBA at the nearest residential property and below 70 dBA at the nearest commercial/industrial property, which is in compliance with relevant federal, state, and municipal requirements (VHB, 2023).

## Air Emissions

Renewable energy, including offshore wind, will benefit the climate by reducing GHG emissions, and benefit public health by improving air quality through the reduction of air pollutant emissions from fossil-fuel burning power plants (Buonocore et.al, 2016). The National Renewable Energy Lab (NREL) considered approximately 3,000 published life cycle assessment studies on utility-scale electricity generation from nuclear, natural gas, coal, hydrogen storage, wind, solar photovoltaics, and other renewable technologies. Results show that from the stages of development to decommissioning, or cradle to grave, coal-fired electricity releases about 20 times more GHGs per kilowatt-hour than solar, wind, or nuclear electricity. Results from the final review also show that total life cycle GHG emissions from renewables, including offshore wind, are much lower and generally less variable than those from fossil fuels (NREL, 2021).

An analysis of air emissions associated with wind energy production modeled in three locations - onshore, shallow-water, and deep-water - in Texas and the Gulf Coast indicates that electricity source in the manufacturing stage of offshore wind components and geographical location of the manufacturing processes were key factors in air emissions (Chipindula et. al, 2018). Coal-derived electricity and consumption of natural resources produce $CO_2$, accounting for 96% of the total air emissions in the manufacturing process. Similarly, the production of methane and sulfur hexafluoride have varying patterns compared to $CO_2$ and nitrous oxide, with production of larger turbine capacities having higher emissions due to the fossil fuel use in manufacturing and the complex production process of components. Methane emissions can be reduced in the case of production and manufacturing where natural gas or petroleum is the main energy source. The total emissions and electricity produced are evaluated on a standard 20-year wind turbine lifespan. Most wind turbines also have a payback period of six months for both energy generation and $CO_2$ emissions, which points to an emission-free period of about 38 times more when compared to emissions during the early extraction, material processing, manufacturing, transportation, and installation phases of offshore wind. This emission-free period highlights the key benefits and importance of offshore wind power in mitigating climate change and reducing emissions in comparison to other electricity-generation sources.

To summarize, for offshore wind projects, the GHG emissions were in the range of 5–7 $gCO_2eq/kWh$ for the onshore location, 6–9 $gCO_2eq/kWh$ for the shallow-water location, and 6–8 $gCO_2eq/kWh$ for the deep-water location (Chipindula et al. 2018). In comparison, the $CO_2$ emissions associated with electricity generation from coal is 1025 g/kWh, 440 g/kWh from natural gas, and 1107 g/kWh from petroleum. This showcases the potential for significantly reducing $CO_2$ emissions over the lifetime of an offshore wind project, in comparison to traditional fuel sources.

The economic value of offshore wind was found to be highest off the coast from New York to Massachusetts, ranging from $40/MWh to $110/MWh (Mills et al. 2018). A 2017 study found that the cumulative air quality benefits of wind and solar between 2007 and 2015 amounted to a value $29.7–112.8 billion. Energy generation from fossil fuels produces large quantities of nitrogen oxides, sulfur dioxide, inhalable fine particulate matter (PM2.5), and toxic metals. The avoidance of these emissions through wind or solar power leads to increased air quality and health. The improvement of air quality due to wind and solar usage is estimated to have prevented 3,000 to 12,700 premature mortalities (Millstein et al., 2017). Similarly, studies suggest that offshore wind in the Mid-Atlantic is capable of producing health and climate benefits, with the largest simulated facility (3,000 MW off the coast of New Jersey) producing approximately $690 million in near-term benefits as of 2017. Based on the study, benefits attributable to avoided sulfur dioxide emissions can be highest, followed by those attributable to avoided $CO_2$, and then nitrogen oxides. Multiple modeled scenarios also suggest that even before considering the value of selling the electricity, the entire cost of an offshore wind facility would be justified through the health and carbon benefits, (Buonocore et.al, 2016).

## Mitigation Innovations

While some effects may be unavoidable, all potential impacts from an offshore wind project are evaluated within a mitigation framework. The aim is to avoid, minimize, or mitigate adverse effects as much as is feasible.

### Onshore Construction Noise Mitigation Measures

All offshore wind projects require best management practices to reduce construction noise to safe, reasonable, and effective levels by employing strategies such as the following:

- Replacing back-up alarms with strobes, as allowed within Occupational Safety and Health Administration (OSHA) regulations, to eliminate alarming sounds where possible.

- Assuring proper equipment functioning and equipment with mufflers and other noise-reducing features.
- Locating especially noisy equipment as far from sensitive receptors as possible.
- Using path noise control measures such as portable enclosures for small equipment (e.g., jackhammers and saws) and quieter construction equipment and methods, as feasible, such as smaller backhoes.
- Limiting the periods of time when construction may occur.
- Maintaining strong communication and public outreach with adjacent neighbors and providing abutters information about the time and nature of construction activities.

The National Institute for Occupational Safety and Health (NIOSH) recommends that workers be exposed to no more than an average of 85 decibels (dBA) of noise over an 8-hour period, with higher levels considered hazardous (American National Standards Institute [ANSI], 2021). Offshore wind construction will comprise variable levels of construction noise exposure to workers based on equipment type and nature of construction activity. However, from the standpoint of human health impacts from onshore noise along shorelines and at residential dwellings, existing research does not indicate any negative impacts on human health from offshore wind construction and operations noise. Further, all onshore noise levels are required to be compliant with state and federal noise limits.

## Air Emissions Mitigation Measures

The EPA issues the final Clean Air Act Outer Continental Shelf air quality permit to offshore wind projects, detailing the air pollution control requirements for the construction and operation of the projects. The permit regulates pollutants from sources such as jack-up barges that will construct each wind turbine and the electrical service platforms. Emissions associated with air-emitting devices used during the operation of the wind farm (e.g., generators used as a source of back-up electricity for space conditioning where sensitive electronics are housed) are also regulated (EPA, 2021).

When considering emissions associated with vessels, construction, operation, and maintenance-related activities, the permit requires stringent "lowest achievable emissions rates" and emissions offsets for nitrogen oxides and volatile organic compounds, as well as "best available control technologies" for particulate matter, $CO_2$, volatile organic compounds, oxides of nitrogen, and greenhouse gases (EPA, 2021).

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