TERM OF COMMISSION: July Session of the July Adjourned Term

PLACE OF MEETING: Roger B. Wilson Boone County Government Center

County Commission Chambers / Conference Call

PRESENT WERE: Presiding Commissioner Daniel Atwill

District I Commissioner Justin Aldred

District II Commissioner Janet Thompson

Director of Joint Communications Chad Martin

Director of Resource Management Bill Florea

Planner Uriah Mach

Planner CeCe Riley

Deputy County Clerk Jodi Vanskike

Public: Robert Hall, Tim Opitz, Mike Sivore, Brent Voorheis, Warren Wood, Jay Hasheider, Richard Fray, Zack Dunn, Tom Weislouher, Nakila Blessing, Carrie March, Susan Goodman, Terrie Nagel, David Nagel, Greg Toul, Stephen Nagel

Conference Call Information:

Number: 425-585-6224 Access Code: 802-162-168

The meeting was called to order at 7:00pm.

Joint Communications

1. **First Reading: Approval of Budget Revision for Purchase of VHF receivers**

Director of Joint Communications Chad Martin stated they are requesting approval for a budget revision for five Astroteck receivers in the amount of $5,975.00. Director Martin stated this would be to move money from a contingency fund to an operating budget classification fund for the receivers at five sites, to fix an immediate need for the Boone County Fire frequencies that have some interference.

Commissioner Atwill stated this is a first reading and requested the Deputy County Clerk schedule this item for a second reading at the next available commission meeting with appropriate order for approval.

P&Z

2. **Goen Acres Plat No. 1. S13-T50N-R13W. A-2. Goen LLC, owner. David Butcher, surveyor.**

Director of Resource Management Bill Florea asked to waive the reading of the report and asked that the clerk be authorized to submit the report into the record with the minutes.

Commissioner Thompson moved now on this day, the County Commission of the County of Boone does hereby receive and accept the following subdivision plat and authorizes the Presiding Commissioner to sign it:

1. Goen Acres Plat No. 1. S13-T50N-R13W. A-2. Goen LLC, owner. David Butcher, surveyor.

Commissioner Aldred seconded the motion.
The motion carried 3 to 0. **Order #302-2021**

3. **A Public Hearing for the purpose of readopting the Boone County Zoning Regulations, including revisions to Section 2, Definitions; Section 15.G, Conditional Use Permits for Commercial Wind Energy Conversion Systems; and Section 29, Wind Energy Conversion Overlay District.**

Commissioner Atwill stated many months ago it came to the Commission's attention that there was an interest in wind farms in Boone County. Commissioner Atwill stated they did not have any regulatory mechanism in place for that, so they asked the Planning and Zoning Commission to take a look at the issues involved and to report back to the Commission. Commissioner Atwill stated the Planning and Zoning Commission took several months to look at things and prepared a comprehensive report. Commissioner Atwill stated since this is now being presented officially to the Commission at this meeting, the purpose this evening is to hear public comment that will have to do with whether or not this should be adopted as is; if it should be modified and adopted; or if it should be rejected. Commissioner Atwill stated there will be two other public meetings about this issue: one in Harrisburg for the Northern District of Boone County and one in Ashland for the Southern District of Boone County. Commissioner Atwill stated, after those town halls are concluded, the issue will come back before the Commission for approval, denial, or modification. Director of Resource Management Bill Florea presented a slide show and copies of that slideshow have been attached to the official minutes for public review. After the slide show presentation, Commissioner Atwill opened the public hearing. Tim Opitz stated he is there on behalf of Renew Missouri. Mr. Opitz stated they are a renewable energy and energy efficiency advocacy group and stated his group brings a lot of experience in this area. Mr. Opitz stated based on his experience, his group is very concerned about the ordinance being discussed. Mr. Opitz stated, in addition to their own policy research, they have reached out to a national group, The American Clean Power Association, who has assisted. Mr. Opitz stated he has a letter from that association that details environmental and economic benefits that wind energy

can bring. Mr. Opitz stated the letter also details concerns about the ordinances and offers input on best practices. Mr. Opitz stated he would like to raise a few concerns tonight. First, this ordinance is not a reasonable restriction. Mr. Opitz stated this ordinance is a ban on wind energy in Boone County. Secondly, this ban will be used to justify limitations on wind energy around the state as unreasonable restrictions. Mr. Opitz stated, when his group went to Resource Management over a year ago to impose reasonable regulations, their Executive Director was told by a staff member that Boone County didn't need the extra revenue and that the wind farms should be built elsewhere. Mr. Opitz stated the ban that was proposed sends a loud and clear message to the County: Boone County doesn't want the economic benefits of wind, Boone County doesn't want environmental benefits of wind, and Boone County doesn't want land owners to be able to earn money from wind farms on their property. Mr. Opitz stated, "In other words, Boone County is closed for business." Michael Sivore from RWE Renewables stated, as one of the largest developers of wind projects in the world, these restrictions as proposed would prevent them from moving forward with their project and will prevent other developers from being able to do anything with wind farms in Boone County. Mr. Sivore stated he would like to request that the Commission consider the letter from American Clean Power. Brent Voorheis, from Harrisburg, MO stated he also believes the regulations as presented will not allow for wind development in Boone County. Mr. Voorheis stated he lives on a family farm where his family has lived since the 1950's. Mr. Voorheis stated he has six generations within this County and he would do nothing that he thought would be a detriment to northwest Boone County or anyone living in northwest Boone County. Mr. Voorheis stated he started this process for a few reasons. Mr. Voorheis stated he could see the benefits to school districts; he could see benefits for green energy; and the third reason was there would be benefits to him. Mr. Voorheis stated, while the money wouldn't change his lifestyle, it might change his kids' or grandkids' lifestyles. Warren Wood, Ameren Missouri Vice President of Regulatory & Legislative Affairs, stated he lives on a farm with an energy pipeline running through his property. Mr. Wood stated Ameren Missouri views the regulations being proposed as an effort to ensure that wind energy projects are good neighbors to the community, and they agree with and support that effort. Mr. Wood stated with that said, they are very concerned that some of the regulations would prohibit wind energy from being built in the County. Mr. Wood stated Ameren is committed to providing affordable and reliable electricity to their customers and producing this energy in Missouri if feasible. Mr. Wood stated they are currently making a transformational change to serve their customers now and in the future. Mr. Wood stated renewable energy, wind especially, is a very important part of this transition. Jay Hasheider stated what he would like to address is the issue of climate change and how wind energy has direct bearing on that issue. Mr. Hasheider stated climate change is happening right now as you look at floods, forest fires, sea level rises, or high temperatures. Mr. Hasheider stated climate change is here and it's bad but tomorrow it will be worse. Mr. Hasheider stated the right thing to do is stop the use of fossil fuels and to start using renewables. Mr. Hasheider stated he would like to discuss the regulations and how they would effectively be a ban on wind energy in Boone County. Mr. Hasheider stated he urges the Commission to look at what other states like Iowa, Minnesota, and Wisconsin are requiring for their wind regulations and he urges the Commission to do the right thing. Richard Fray stated he is currently one of the members building the wind farm in the northern counties of Missouri, referred to as High Prairie Wind. Mr. Fray stated he has been working at the High Prairie Wind Farm for a couple of years now, doing erosion control and transporting. Mr. Fray stated, this project has provided him good, consistent work that has allowed him to earn an honest paycheck. Mr. Fray stated from his experience, much of the crew in High Prairie is from out-of-

state. Mr. Fray stated local area, higher provisions ensure money being paid to workers is being spent in the communities we live in. Mr. Fray stated he joined his union because he wanted a good paying career, not just a job. Mr. Fray stated, like any job, he went through training, learning both in the classroom and on the job site. Mr. Fray stated, as an apprentice, he learned how to safely perform a wide variety of work and that not every guy on the worksite has the same level of training as he does. Mr. Fray stated in addition to provisions seeking local higher commitments, he urges the Commission to consider adding a Department of Labor recognized apprenticeship program to all contractors and subcontractors seeking work on a wind farm. Mr. Fray stated by doing this, it would help maintain the safety of workers and the safety of neighbors who rely on the wind turbines to be built properly. Zack Dunn, Director, Governmental Affairs at Eastern Missouri Laborers' District Council, stated in 2018, their international union conducted a study on the impact of wind farm local hiring practices in Minnesota. Mr. Dunn stated developers were bringing work crews from other states to complete the construction and out-of-state work crews would often receive a per diem of $100.00 per day, which was often the only money they spent while in these communities. Mr. Dunn stated, when the project was complete, the workers would take their wages and go to other parts of the country to their next project. Mr. Dunn stated, with local workers, they live in the communities where they are building these wind farms and spend their money at local businesses and hospitals and pay various taxes in the community. Mr. Dunn went on to say his company thinks the Commission should add language to seek these commitments from developers, contractors and subcontractors that apply for a WECON permit. Mr. Dunn stated this provision would support local workers, local businesses and the overall community. Tom Weislouker stated he hasn't found much favorable about wind energy except what's listed on the wind companies' websites. Mr. Weislouker stated he has attended many Planning and Zoning Commission meetings and has followed the process they went through and he feels they did a "bang up job" on the regulations. Mr. Weislouker stated he found Planning and Zoning consulted multiple sources; they have reworked and clarified their wording; they have considered input from multiple interest groups, public and private sources, experts, and layman, and drafted regulations that would be fair while protecting the values of both interested and non-interested citizens, including property owners. Mr. Weislouker stated he has heard many people say that these regulations are effectively a ban on wind energy, but he would like to state that the regulations are where they need to be. Mr. Weislouker stated Boone County is ten times more densely populated than other areas that have wind farms and he states they haven't worked all that well in some of those areas. Mr. Weislouker stated there are two people in attendance from Schuyler County, MO, and he hopes they get a chance to speak and tell their story. Nakila Blessing stated she has brought some pictures of her home and land in Schuyler County for the official record. Ms. Blessing stated she lives in the middle of a 400-megawatt project that includes 175 2.2-megawatt and 3.45-megawatt wind turbines that are approaching 500 feet tall. Ms. Blessing stated the closest turbine to her home is 3400 feet and there are 13 turbines within two miles. Ms. Blessing stated what she, her family, and her neighbors had hoped for their future was stolen from them. Ms. Blessing stated she is jealous of people who can peacefully sleep in their homes, enjoy a quiet night on their deck listening to the sounds of nature, and people who get to spend their days without wind turbines or construction traffic. Ms. Blessing stated she would like the Commission to take into consideration what they are willing to sacrifice. Ms. Blessing asked if the Commission was willing to sacrifice residents, any resident of Boone County, for promised tax revenue. Ms. Blessing asked if the Commission was willing to consider any resident collateral damage for so called progress. Ms. Blessing stated if one

person, one family or one home is affected, is it worth it? Where do you draw the line? Ms. Blessing stated as more wind and solar are being brought online, more electricity prices will increase because wind and solar are unreliable. Ms. Blessing stated if the wind doesn't blow or the sun doesn't shine, they can't produce. Robert Hall stated he fully supports the Planning and Zoning proposed regulations. Mr. Hall stated, as others have pointed out, the regulations written are rational and very well-supported by public hearings. Mr. Hall stated, if the concern is the proposed regulation would make it very difficult for a wind energy project to meet the requirements, then it's obvious that the land patterns in this area are simply incompatible with wind turbine. Carrie March from Schuyler County, MO, stated her husband and she built their farm in Northwest, MO, on land where they planned to spend the rest of their lives. Ms. March stated she was first approached regarding wind energy in 2018 and today her property is surrounded by wind turbines. Ms. March stated, the closest turbine to her home is 2100 feet away and they have 16 wind turbines within 1.8 miles of their home. Ms. March stated, when they were approached by a wind rep, they were told they were the last ones on their road to sign and that they were holding the project up for the rest of their neighbors. Ms. March stated in the end, five neighbors on their road signed and four did not. Ms. March stated after taking her contract to a lawyer and realizing it would give the companies too much control of her land, they decided it was not for them. Ms. March stated her neighborhood was turned into a construction zone, all trucks had out of state license plates and the roads were tore up by the concrete trucks that often ran people off the road. Ms. March stated the noise of construction was tough to get used to and having so many strangers around always was unsettling. Ms. March stated the crews would shut down roads for twenty minutes at a time without any warning and she would urge anyone living in a neighborhood where wind turbines are going in to move completely out during construction, though her roads are still not fixed two years later. Ms. March stated turbines immediately changed the landscape at her house, but one of the worst parts was how suffocating they felt. Ms. March stated they had destroyed all the beauty that had previously been there, and she was not prepared for the first time she heard the audible noise. Ms. March stated the wind turbine was 1.6 miles away and she couldn't believe they could hear it at all, but the closer the wind turbine was, the worse the sound was. Ms. March stated the turbine 1 mile away was the one that drove them inside, but the day they turned on the turbine at 2100 feet from their house was the day that Ms. March and her husband knew they would have to leave. Ms. March stated by the time they had all the turbines functional, the sound was unbearable. Ms. March stated it's hard to describe going from such a quiet setting to this level of noise. Ms. March stated there are days that the wind turbines are off or the noise isn't as loud but never knowing when or how long the days of unrelenting noise will last starts to control your life. Ms. March stated there are times they can hear the wind turbine one mile away louder than one at 2100 feet and it's completely unpredictable. Ms. March stated, when the windows in her house are shut, it is more like a pulse or a throbbing but with the windows open, it's like having the turbine in your backyard. Ms. March stated they must leave the curtains closed because there is something spinning or flashing out every window. Ms. March stated, her oldest son has experienced more headaches and she has twice had to pick her sons up from school, which also has wind turbines within a mile, with headaches so bad they were vomiting. Ms. March had a handout she asked to be included in the official minutes. Susan Goodman stated she lives in Harrisburg, MO right in the middle of where the wind farm project would be. Ms. Goodman stated she is shocked to find out the truth about wind energy. Ms. Goodman stated three and a half years ago she was a pro renewable advocate and then when she found out they wanted to put them within a thousand miles of her house, she was motivated to investigate it

deeper. Ms. Goodman stated unless you are personally affected, you can believe all the things you're being told but when you do dig deeper you find something else. Ms. Goodman stated she has found smaller turbines hold up better with less health effects, so she is here today to support the regulations. Terrie Nagel stated she lives in the area that will be affected by the wind farm and stated when she read the article in the Missourian, she was shocked to find out the problems with these industrial wind factories. Ms. Nagel stated most of the people in Harrisburg don't want the wind farms in their area. Ms. Nagel stated there was an article in the Tribune recently discussing the wind turbines that were just left by a company in Oklahoma with no plan on how to remove them. Ms. Nagel stated this is one reason why regulations are needed. David Nagel stated he has been a Northwest Boone County resident for 35 years and retired from the MU Power Plant after 35 years of service. Mr. Nagel stated he's been retired now about three years and one thing he enjoys is sitting on his back porch to have his coffee in the morning while watching the sunrise. Mr. Nagel stated these wind turbines would lower his quality of life and asked who is going to want his property if they come in. Mr. Nagel stated he knows other people who have recently bought property in Northern Boone County for the purpose of building on it but aren't sure they want to drop anymore money into the property. Mr. Nagel stated in conclusion, he is all for green energy, just not in his backyard. Greg Toul stated he lives in Harrisburg, MO and is here to speak against wind turbines. Mr. Toul stated he, along with many others in his town, aren't sure why this is occurring not just in their back yard but to anybody, anywhere, anytime. Mr. Toul stated one concern is the loss of property value which is 40%-60% across the board. Mr. Toul stated if these wind farms are allowed, the value of people's homes are going to go down and so far, no one has taken accountability for that. Stephen Nagel stated he would like to thank the Planning and Zoning Commission for the number of hours they put into putting the presentation together. Mr. Nagel stated he lives on North Route E in Boone County and is here to ask the Commission to protect the small landowners of the County who vote and pay taxes here. Commissioner Atwill stated if there is no one else wishing to speak, he will now close the Public Hearing. Commissioner Atwill stated there will be two more public hearings being held at town halls, one in Ashland and one in Harrisburg. Commissioner Atwill stated after those are completed, the information gathered at those will be compiled into our record. There will then be a discussion with all three Commissioners, who will come to some sort of conclusion. Commissioner Atwill stated good points have been made tonight and thanked everyone for coming.

Sheriff's Office

4. **Second Reading: St. Charles City K-9 Basic Training Contract (First Read 07.22.21)**

Commissioner Aldred moved now on this day, the County Commission of the County of Boone does hereby approve the attached K-9 Cooperative Training Agreement between Boone County and the following:

- St. Charles City Police Department

Terms of the agreement are stipulated in the attached Agreement. It is further ordered the Presiding Commissioner is hereby authorized to sign said K-9 Cooperative Training Agreement.

Commissioner Thompson seconded the motion.

The motion carried 3 to 0. **Order #303-2021**

Road & Bridge

5. **Second Reading: The Missouri Department of Conservation CART program participation (First Read 07.22.21)**

Commissioner Thompson moved now on this day, the County Commission of the County of Boone does hereby authorize participation in the Missouri Department of Conservation's County Aid Road Trust (CART) program as contemplated in the attached program mailing packet.

The Presiding Commissioner and Director of Road & Bridge are authorized to execute the documents reasonably necessary to effectuate Boone County's participation in this CART program.

Commissioner Aldred seconded the motion.
The motion carried 3 to 0. **Order #304-2021**

IT

6. **Second Reading: Budget Amendment CAD to CAD Data Exchange / MO 911 Service Board Grant (First Read 07.15.21) Open Public Hearing**

Commissioner Atwill open and closed the public hearing.

Commissioner Aldred moved now on this day, the County Commission of the County of Boone does hereby approve the Budget Amendment for the CAD to CAD Data Exchange / MO 911 Service Board Grant.

The terms of the agreement are stipulated in the attached Agreements. It is further ordered that the Presiding Commissioner is authorized to sign said Agreements.

Commissioner Thompson seconded the motion.
The motion carried 3 to 0. **Order #305-2021**

Purchasing

7. **Second Reading: Contract Amendment #3 for Signature for Boone County: 129-123116SS - Computer Aided Dispatch System (First Read 07.20.21)**

Commissioner Thompson moved now on this day, the County Commission of the County of Boone does hereby approve the Sole Source Contract 129-123116SS - Computer Aided Dispatch System which was approved by Commission for award to SunGard Public Sector LLC on March 24, 2016, Commission Order 148-2016.

This Amendment assigns the contract to CentralSquare Technologies, LLC (CentralSquare) and it adds the Tellus Unify product.

$26,590 is budgeted for this purchase.

Commissioner Aldred seconded the motion.
The motion carried 3 to 0. **Order #306-2021**

Commission

1. Public Comment

none

2. Commissioner Reports

none

Attest:

Brianna L. Lennon

Clerk of the County Commission

Daniel K. Atwill

Presiding Commissioner

Justin Aldred

District I Commissioner

Janet M. Thompson

District II Commissioner

Staff Report for County Commission
RE: P&Z Agenda Items
July 27, 2021

Plats

At its July 15, 2021 meeting, the Planning and Zoning Commission approved the plat of *Goen Subdivision* by consent. I ask that you waive the reading of the staff report and authorize the clerk to insert the it into the meeting minutes.

Goen Subdivision

The property is located on E Highway 124, approximately 4 miles west of the City of Hallsville. The property is 10.01 acres in size and was created by administrative survey in June of 2021. It is zoned A-2 (Agriculture) and is surrounded by A-2 zoning, all of which is original 1973 zoning. This proposal divides the administrative survey tract into three lots, each being 3.19, 3.18, 3.26 acres, respectively. The property within this plat proposal is currently undeveloped.

The property has frontage on W Hwy 124; however, MODOT has stated that Lot 6 does not have direct access due to site distance criteria. A paired driveway with proposed lot 5 or 7 has been identified as the only solution that will meet regulations. The applicant has submitted a request to waive the traffic study requirement.

The subject property is located in Consolidated Water #1, the Boone Electric Cooperative service area, and the Boone County Fire Protection District. Wastewater has been proposed as on-site lagoons. The health department has been made aware of this proposal and has indicated no foreseen issues at this time. Any new development on these property's on-site wastewater treatment systems will require permitting from the Columbia/Boone County Health Department.

The property scored 31 points on the rating system.

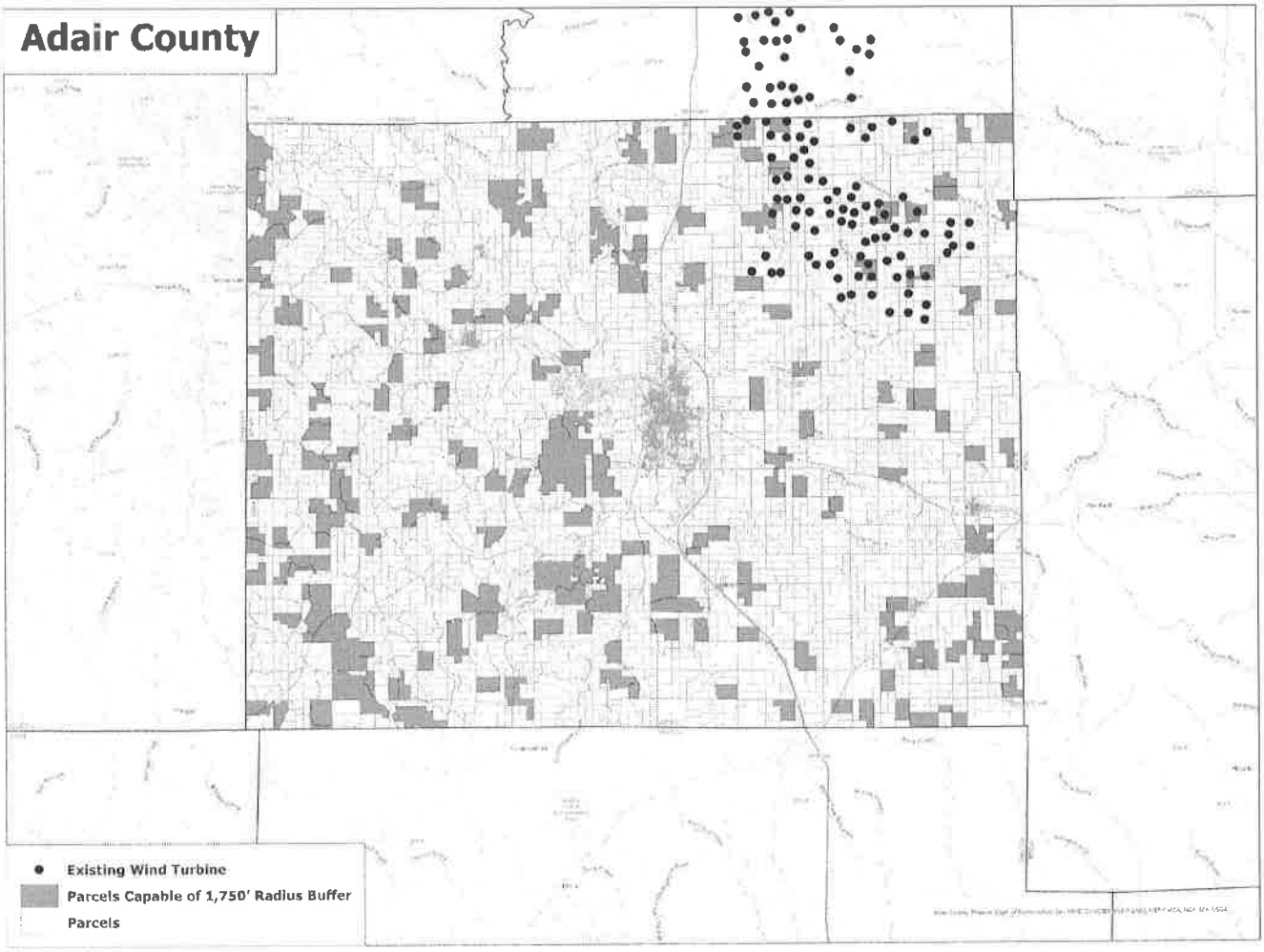
Staff recommended **approval** of the plat subject to the following condition that has been satisfied:

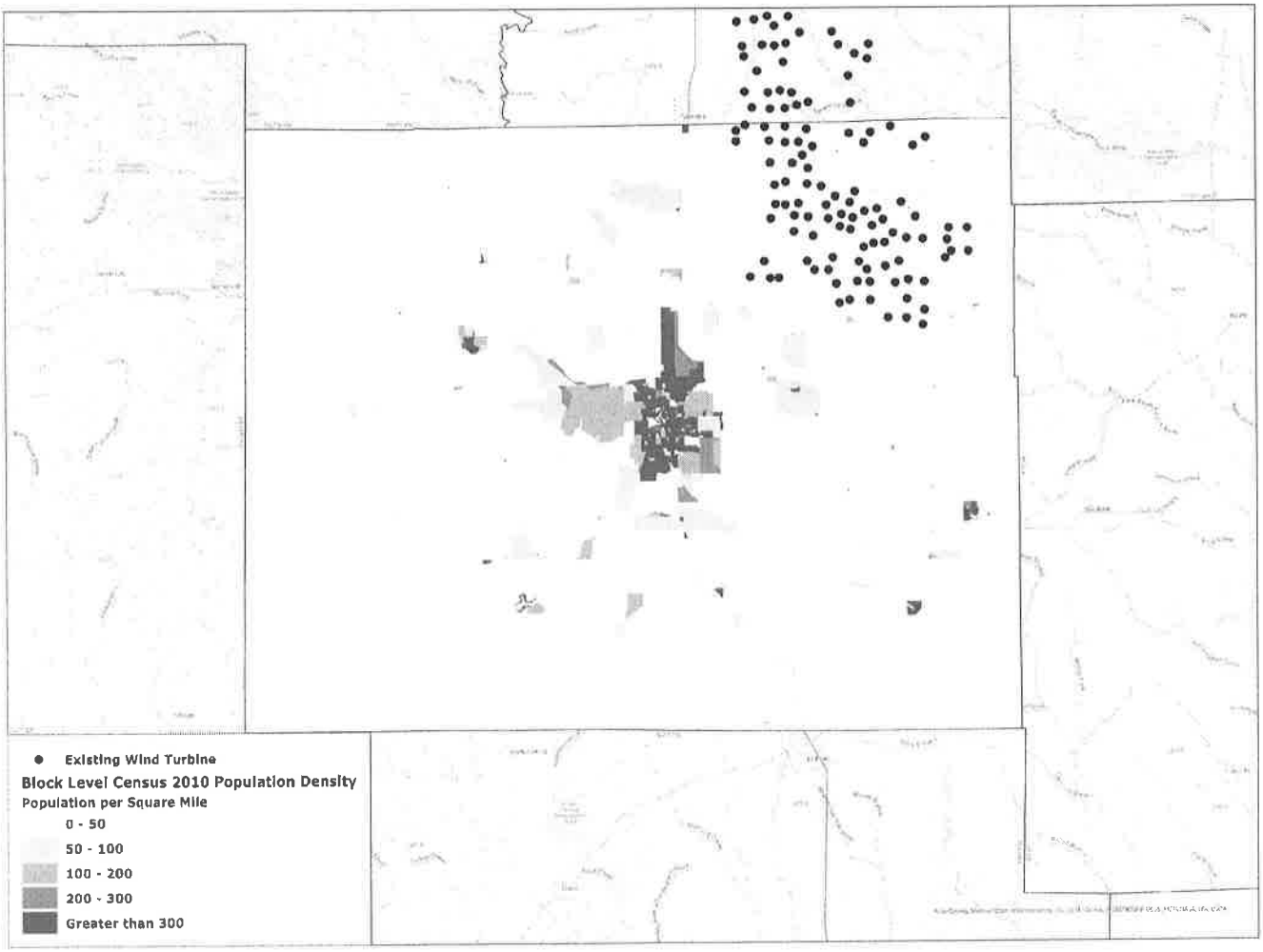
1. Access for Lot 6 is subject to the approval of both MODOT and the Director.

	Boone	Adair	Howard	Schuyler
2020 Population	180,463	25,343	10,001	4,660
Population % Change	▲11%	▼-1%	▼-1.4%	▲ 5.2%
2010 Population	162,642	25,607	10,144	4,431
Area	691 mile^2	569 mile^2	253 mile^2	308 mile^2
Population Density people per square mile	240/mile^2	45/mile^2	21/mile^2	14/mile^2
Housing Units	77,314	11,542	4,591	2,106
Assessed Valuation	3.1 Billion	343 Million	133 Million	74 Million

Source: data.census.gov 2019
Missouri Association of Counties

Adair County

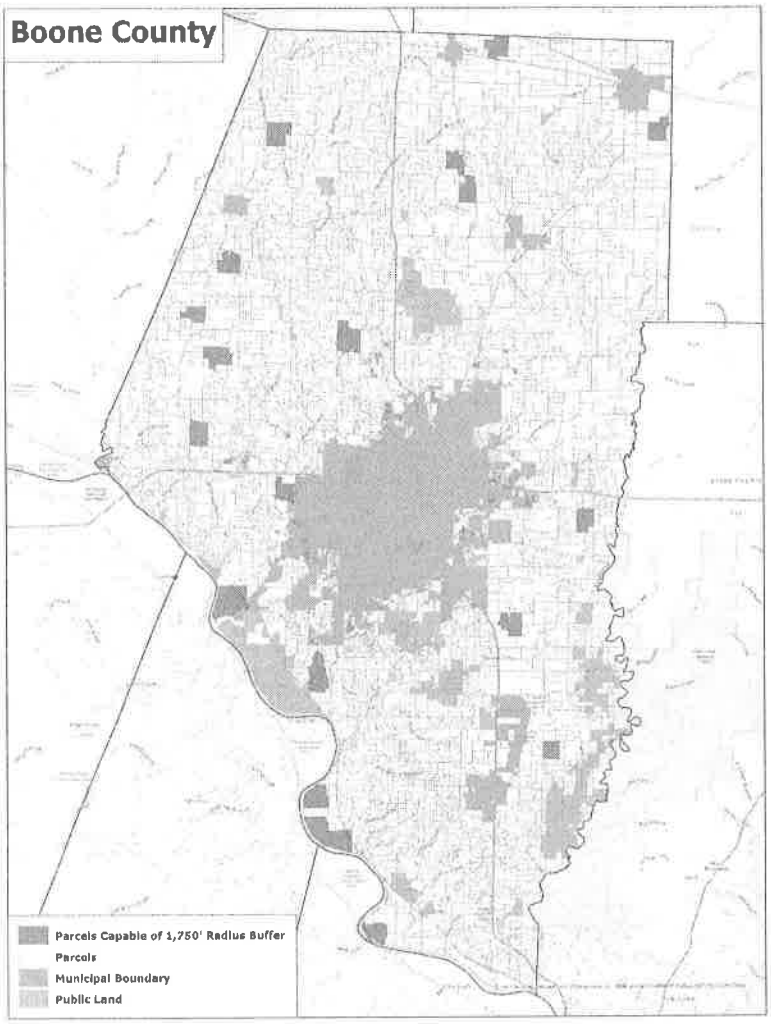


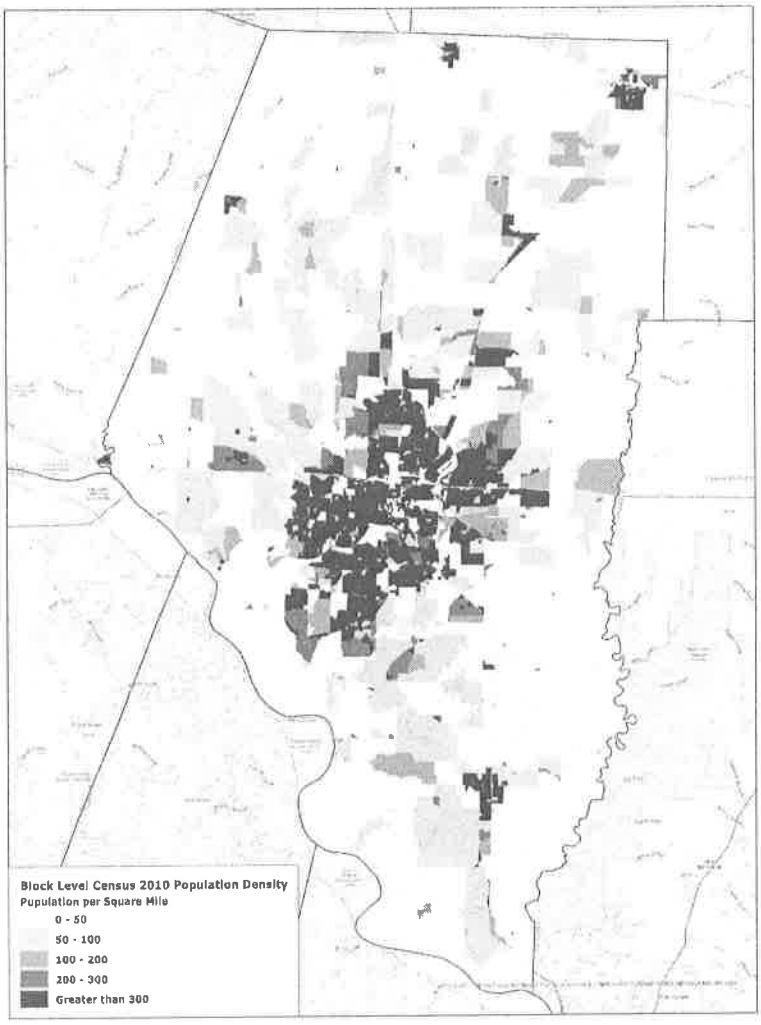


Boone County Wind Farm Regulations Timeline

as of 7/26/21

2018	July	County Commission approved a Conditional Use Permit for a met mast tower in northern Boone County.
2019	February	A private company (E.ON) sent several residents near Harrisburg letters stating the company's intent to explore whether a wind farm could be viable in the area.
	March	Harrisburg residents organized an informal public meeting to discuss their questions and concerns regarding the proposed wind farm project
	April	The County Commission directed Resource Management to work with the Planning and Zoning Commission to draft policies regarding commercial scale wind farms PZ began holding work sessions to discuss details. In total there would be 14 work sessions between April 2019 and May 2021
	May	A series of guiding principles became clear that the Planning and Zoning Commission would use to prioritize discussion regarding Wind Regulations: • A high level of community support for all proposed wind farms; • A high commitment to public safety, health, and welfare; • Minimizing impacts to non-participating properties and property owners; • Ensuring mitigation of any degradation of public transportation infrastructure; • Minimizing impacts to the natural environment; • Ensuring a fair process
	June	Energy and Environment Commission presented findings to the Planning and Zoning Commission
	July	The PZ Commission, after thorough research & guidance from the EEC, began making preliminary decisions regarding setback distance and interest in modeling the wind regulations on existing Character Preservation Overlay District
	December	The Wind Energy Conversion Overlay District framework was established, and staff began drafting regulations. This framework also included the intent for each turbine to apply for a Conditional Use Permit in addition to the District
2020	January	The PZ Commission further discussed their interest in having a high amount of public input & requiring wind farm applicants to successfully attain a clear majority of neighbor's approval before applying for a WECOD
	March	The COVID-19 Pandemic temporarily delayed progress on regulations and hosting public meetings.
2021	January	The PZ Commission reviewed past findings and refined draft regulations presented by staff with intent to host Public Hearings in the coming months
	April	Three Public Hearings were hosted in Harrisburg, Ashland, and Columbia. Staff collected public comment provided both at hearings and through the dedicated WECOD email address
	May	After reviewing public input, staff presented an updated draft of the WECOD Regulations and a Wind Turbine specific Conditional Use Permit (WECS-C CUP) to the PZ Commission. The drafts were approved unanimously.
	July	Draft regulations were brought to the County Commission for consideration


Boone County
Parcels Capable of 1,750' Radius Buffer
Parcels
Municipal Boundary
Public Land


Block Level Census 2010 Population Density
Population per Square Mile
0 - 50
50 - 100
100 - 200
200 - 300
Greater than 300

Wind Farm Regulations 2021
Public Hearing Presentation

July 27, 2021

County Commission

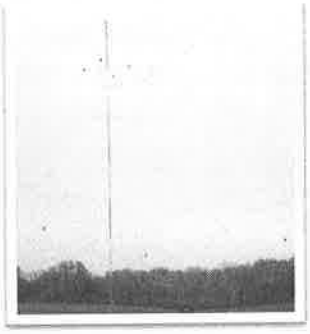
Background

In July 2018 County Commission approved a Conditional Use Permit for a met mast tower in northern Boone County.

The applicant, Mike Sivore, with E.ON Climate and Renewables, testified that there are several factors that his company considers when deciding on a location for a windfarm, namely:

- Supportive community;
- Ability to distribute the electricity;
- Ample wind.

Mr. Sivore stated that he felt the first two factors were present, which left *wind* and thus the need for the met mast.



Met Mast tower in Harrisburg, standing 199' tall.
Provided by Missourian article published May 21, 2019

Background

In March 2019, Harrisburg residents organized an informal public meeting to discuss their questions and concerns regarding the proposed wind farm project

- A County Commissioner and then Director of Resource Management were in attendance.

In April 2019, PZ Commission began to draft policies regarding commercial scale wind farms

- PZ began holding work sessions to discuss details. In total there would be 14 work sessions between April 2019 and May 2021

Through these work sessions the following guiding principles emerged:

- A high level of community support for all proposed wind farms;
- A high commitment to public safety, health, and welfare;
- Minimizing impacts to non-participating properties and property owners;
- Ensuring mitigation of any degradation of public transportation infrastructure;
- Minimizing impacts to the natural environment;
- Ensuring a fair process

Process overview

Express interest in establishing WECS-C (Commercial Wind Farm)

Step 1: Apply for Wind Energy Conversion Overlay District (WECOD)

Step 2: Apply for Conditional Use Permits for towers and accessory structures within WECOD

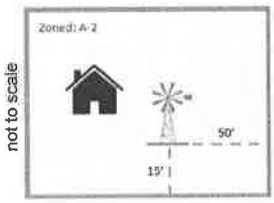
Applicant must meet **all** criteria for approval, pay fees, and meet established timeline

Clarification

Existing Regulations

WECS-S Small Residential Turbines

On-site **personal** use
Location: Agriculture or Residential Zoned



Setback: 6'- 50'

Height: 35'

In excess: +1' height = +1' setback

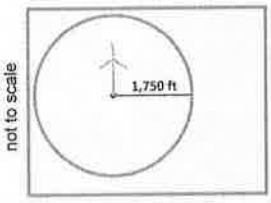
Neighbor support not necessary

CUP required **IF** height over 100'
Mailed notice to all property owners within 1000'

Proposed Regulations

WECS-C Commercial Wind Turbines

Off-site **commercial** use
Location: Agriculture or Industrial Zoned



Setback: 1750'

Height: 355'

Neighbors would need to support

WECOD required
CUP required

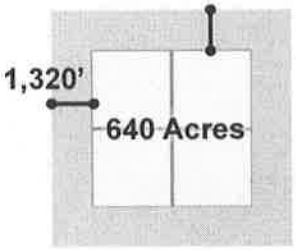
WECOD (Wind Energy Conversion Overlay District)

WECOD is composed of two parts:

- Primary District
- Buffer Area

Primary District: This is the area wind turbines may be located in. It's based on location of property proposing to establish a Wind Farm. The minimum size is **640 Acres** (4 contiguous Quarter-Sections)

Buffer Area: **NO** wind turbines may be constructed here. The buffer extends outward from the perimeter of the Primary District to **1,320 feet** (1/4 mile)



WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR**

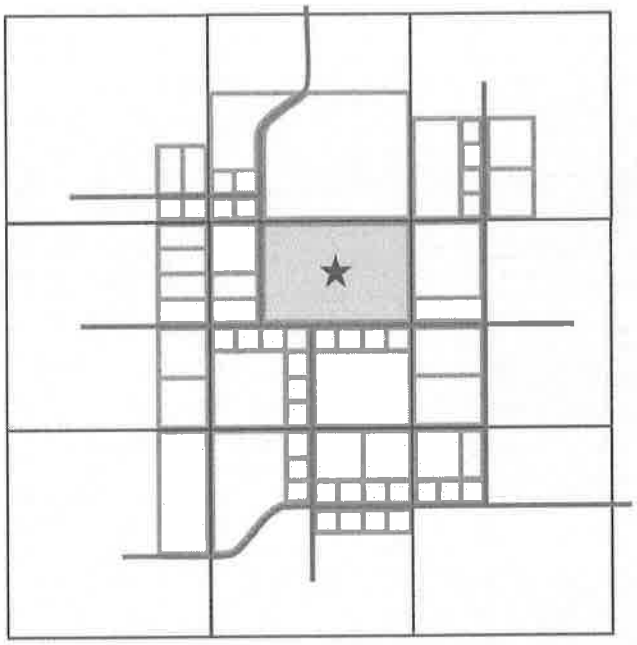
KEY

= Property Line

= Section

= Farmer STAR Property

= Roads



WECOD (Wind Energy Conversion Overlay District)

Example: If Farmer **STAR** wanted to establish a Commercial Wind Farm on his 240-acre piece of land he would need to apply for a WECOD that contains 4 contiguous quarter sections.

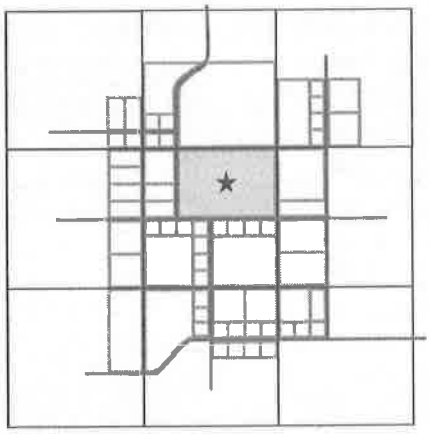
KEY

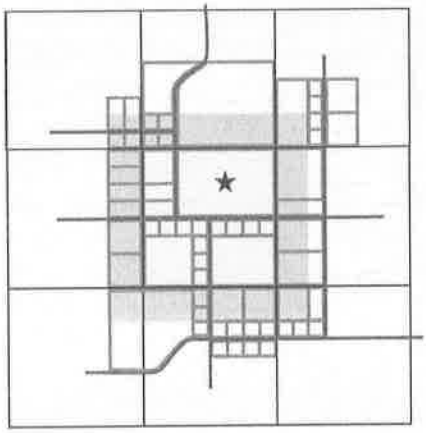
= Property Line

= Section

= Farmer STAR Property

= Roads





Primary District

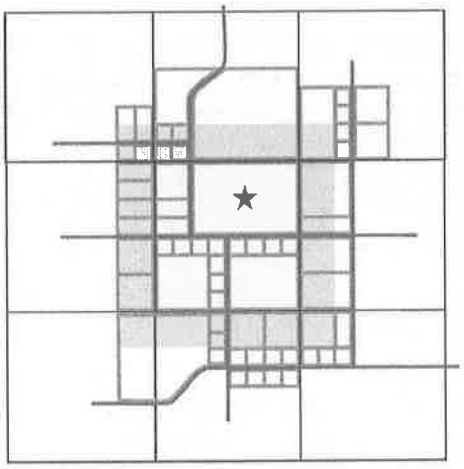
16 Properties totaling 640 Acres

Buffer Area

26 Properties totaling 800 Acres

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **submit a petition** to the Director of Resource Management which includes the notarized signatures of:



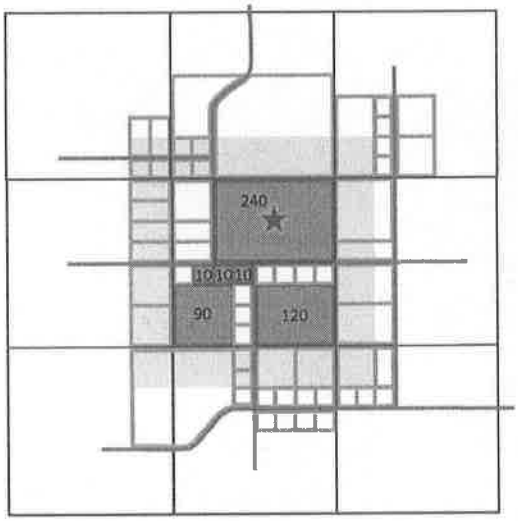
A.) The owners of at least 75% of the ***total acreage*** within the primary district

B.) at least 67% of the ***property-owners*** within the primary district

C.) at least 67% of the ***property-owners*** within the buffer area

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a petition to the Director of Resource Management which includes the notarized signatures of:



6 owners (**240**+120+90+10+10+10) = **480**

A.) The owners of at least 75% of the total acreage within the primary district

B.) at least 67% of the property-owners within the primary district

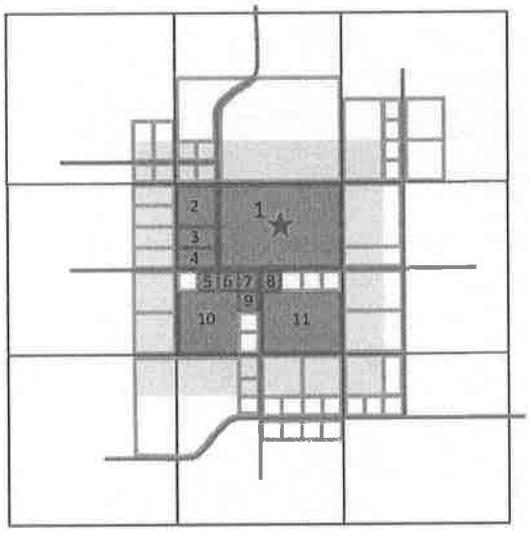
C.) at least 67% of the property-owners within the buffer area

Equation:
Primary District includes: 640 Acres

640 x 75% = **480** Acres ~ Petition signers must own at least 480 Acres

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a petition to the Director of Resource Management which includes the notarized signatures of:



A.) The owners of at least 75% of the total acreage within the primary district

B.) at least 67% of the property-owners within the primary district

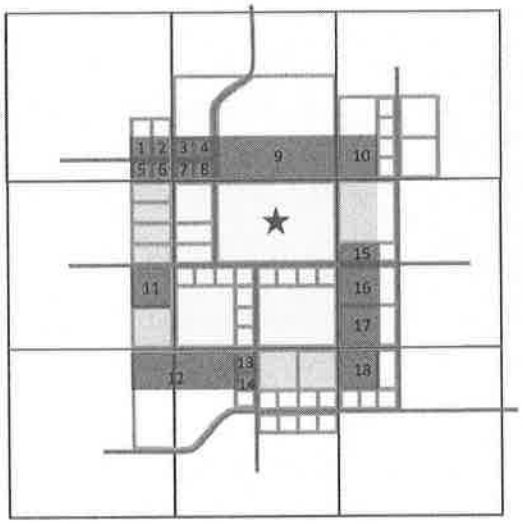
C.) at least 67% of the property-owners within the buffer area

Equation:
Primary District includes: 17 owners (including Farmer **STAR**)

17 x 67% = 11.39 ~ rounds to **11** property-owners must sign petition

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a petition to the Director of Resource Management which includes the notarized signatures of:



A.) The owners of at least 75% of the total acreage within the primary district

B.) at least 67% of the property-owners within the primary district

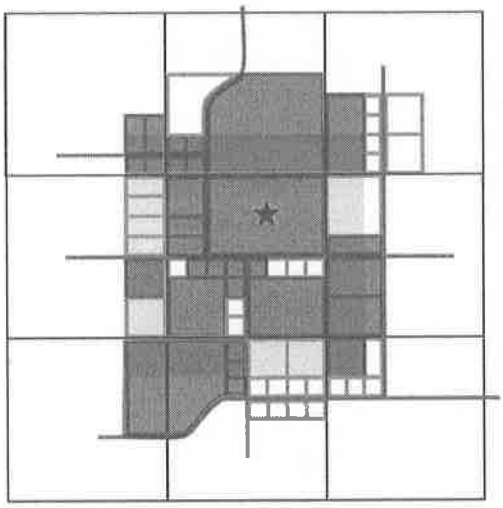
C.) at least 67% of the property-owners within the buffer area

Equation:
Buffer Area includes: 26 owners

26 x 67% = 17.72 owners ~ rounds up to **18** owners must sign petition

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** must meet **ALL** of the signature requirements in order to be **considered*** for a WECOD



A.) The owners of at least 75% of the ***total acreage*** within the primary district

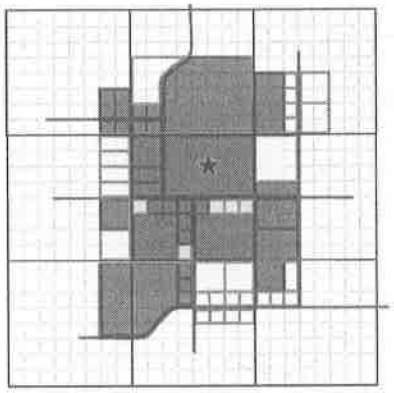
B.) at least 67% of the ***property-owners*** within the primary district

C.) at least 67% of the ***property-owners*** within the buffer area

*Policy based on existing regulations regarding Character Preservation Overlay Districts

WECOD (Wind Energy Conversion Overlay District)

Example: IF Farmer **STAR** can get the required signatures on the petition, THEN he would need to meet **series of criteria**

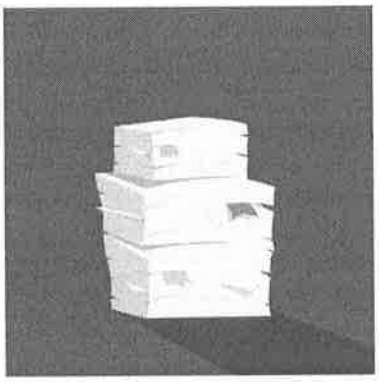


- Submit Complete Application
- Pay Fees
- Notify Neighbors
- Meet Approval Standards
- Meet Siting and Performance Standards

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including an:

Overlay District Plan



includes, but not limited to:

- Legal Description of land
- Aerial Photography of region
- Location and dimensions of **existing** structures
- Location and dimensions of **proposed** structures
- All environmentally sensitive areas within WECOD

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including a:

Computer Generated Visual Simulation

includes, but not limited to:

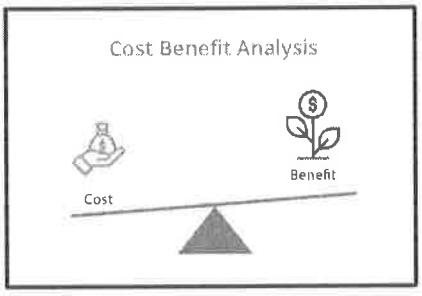
- Impacts from turbine blades on surrounding area
- Viewpoints from houses who did **not** sign the Petition for Application within District
- Viewpoints from houses 1000' outside of WECOD boundary
- Additional key viewpoints as determined by PZ Commission

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including an:

Economic Cost Benefit Analysis

includes, but not limited to:



- Impact of the project on local and state economy
- Amount of **property** taxes to be generated
- Amount of **sales** taxes to be generated
- Number of permanent jobs gained and estimated payroll
- Costs associated with impact on County infrastructure

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including an:

Environmental Assessment

includes, but not limited to:

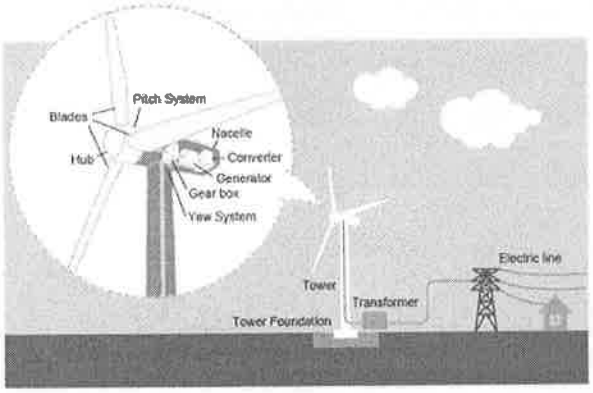
- Must follow United States Fish and Wildlife Service Land Based Wind Energy Guidelines
- Impact on wildlife and wildlife habitat
- Impact on soil erosion, and water quality
- Noise levels, shadow flicker and blade glint

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including a:

Description of Turbine(s)

includes, but not limited to:



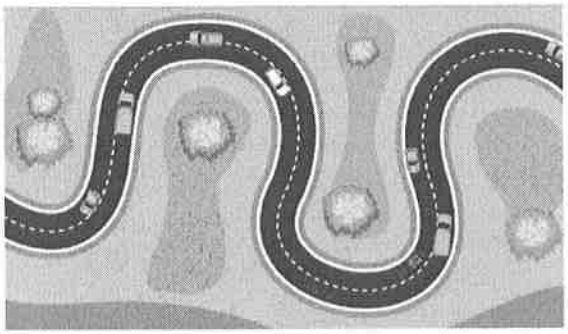
- Type of Turbine, Model number
- Size of tower, blades, foundation, etc.
- Construction Materials
- Color Scheme
- Performance, safety, and noise characteristics

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to submit a **completed application** including a:

Traffic Plan

includes, but not limited to:



- Anticipated volume of traffic during/ after construction
- Routes for oversized and heavy equipment
- Method of assurance regarding road repair to public entities
- A Transportation and Infrastructure Mitigation Plan shall be developed approved by County Chief Engineer

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to pay **all associated costs** including:

Pay Fees

includes, but not limited to:

- Public Notice Fees
- Costs of completing application documentation
- Review fee determined by County Commission

WECOD (Wind Energy Conversion Overlay District)

Example: County will **notify** the following when public hearings occur on Farmer **STAR**'s behalf:

Notice Procedures

includes, but not limited to:

- All property owners within the proposed WECOD
- All property owners within 1000' of the boundary of WECOD
- Newspaper with circulation in their area including a locality map, such as:
    - Columbia Daily Tribune
    - Centralia Fireside Guard
    - Boone County Journal

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to pass Commission **Approval Standards** including demonstrating:

Natural and Biological Resources

includes, but not limited to:

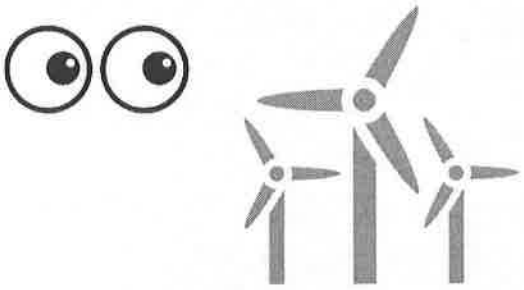
- Turbines should not be located in areas that have a large potential for biological conflicts
- Avoid large intact areas of native vegetation that haven't been disturbed by man made developments
- Avoid areas that would interfere with important wildlife migratory corridors and staging areas.

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to pass Commission **Approval Standards** including demonstrating:

Visual Impacts

includes, but not limited to:



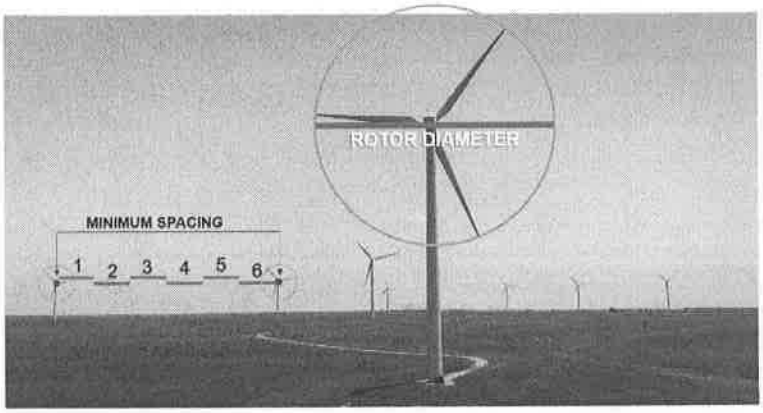
- Avoid sites that are visible from scenic byways, scenic overlooks, public parks, Conservation Areas, and Wildlife Refuges
- Supporting structures, roads, and fences on the site should be minimized
- Turbines should appear similar and shall be a shade of white

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to pass Commission **Approval Standards** including demonstrating:

Visual Impacts

includes, but not limited to:



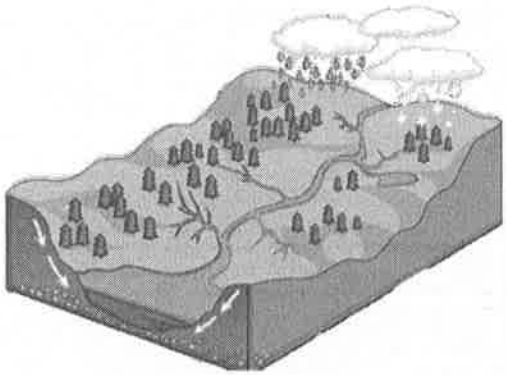
- Each turbine shall maintain a minimum spacing of six (6) times the diameter of its rotor from any other turbine
- Intra-project power lines having a voltage of 34,500 volts or less shall be buried
- Transformers and other electric equipment should be hidden from view

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to pass Commission **Approval Standards** including demonstrating:

Soil Erosion and Water Quality

includes, but not limited to:



- Avoid construction activities on slopes that are steep or susceptible to erosion
- The number of improved private access roads and construction staging areas should be kept to a minimum
- One-lane private access roads are recommended
- The number and size of staging areas should be minimized

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **meet siting and performance standards** including:

Noise Management

includes, but not limited to:

- The average adjusted total day-night sound exposure shall not exceed 45 dBA Ldn
  - Acceptable noise level in accordance with applicable guidelines* and standards** available
- The measurements, modeling, and analysis of said study must conform to strict standards
- If the WECS-C is determined to be out of compliance, it shall be shut down until compliance can be demonstrated

* Policy based on findings from: W.H.O. ***Environmental Noise Guidelines*** *for the European Region*

** ANSI ***Quantities and Procedures for Description and Measurement of Environmental Sound –*** *Part 4: Noise Assessment and Prediction of Long-term Community Response*

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **meet siting and performance standards** including:

Visual Impacts

includes, but not limited to:

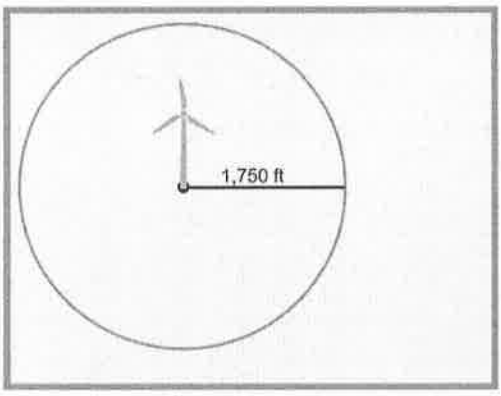
- Turbines shall have the same number of rotor blades, spinning in the same direction
- Turbines should have the same height from blade tip to the ground
- Clusters of machines shall be limited to no more than 12 machines per cluster.
- The maximum height of the turbines should be 355 feet.
- Outdoor storage is generally not permitted, except during construction

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **meet siting and performance standards** including:

Safety

not to scale



includes, but not limited to:

- Turbine shall maintain a minimum clearance of 15-feet from the ground
- Individual wind turbines shall be set back 1,750-feet from all public road rights of way and all property lines
    - Planning and Zoning commission considered several setback* requirements as a balance between safety, equity, and other community concerns
- All WECS-C shall be equipped with an automatic fire suppression system.

* Policy based on findings from: "A method for defining wind turbine setback standards" published in the academic journal Wind Energy

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **meet siting and performance standards** providing:

Financial Security

Ensures that the project owner provides adequate funding to pay the costs associated with:

- Decommissioning and Site Reclamation
- Removal of individual turbines and accessory structures in the event of abandonment.

Any entity providing Security must be authorized to provide such Security in the State of Missouri and must be acceptable to the County Commission.

Security = Estimated Decommissioning and Site Reclamation Cost x (1.5)

WECOD (Wind Energy Conversion Overlay District)

Example: Farmer **STAR** would need to **meet siting and performance standards** providing:

Reclamation

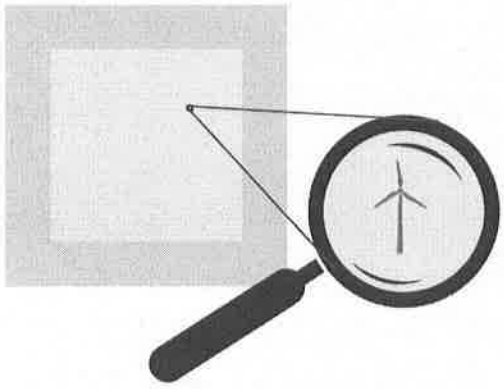
Owner Initiated: When the project has completed its life span, the owner shall abide by County standards to reclaim land. Financial Security will be released.

County Initiated: If owner has abandoned project, the County may use provided Financial Security to complete the reclamation of land after a public hearing process is completed.

Tax dollars are <u>not</u> to be spent on County Initiated Reclamation

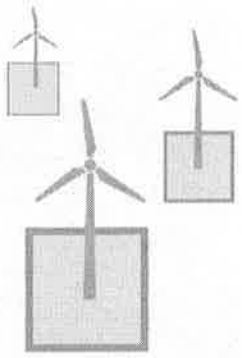
WECOD

(Wind Energy Conversion Overlay District)



CUP

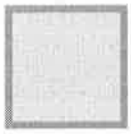
(Conditional Use Permit)



CUP (Conditional Use Permit)

WECS-C
Wind
Turbine

=



CUP

Every turbine and accessory structure must be covered by a Conditional Use Permit –

- Applicant must apply for a CUP
- The CUP application must provide details ***specific*** to the structure's location and conditions

CUP (Conditional Use Permit)

The applicant would need to provide a wide variety of documentation **in addition to** the application from the *corresponding* WECOD for each CUP

including, but not limited to:

- Project Owner Information
- A detailed Site Plan
- Environmental Assessment
- A summary of the Transportation and Infrastructure Mitigation Plan
- Detail Description of Turbine(s) including size, height, rotor material, etc.
- A plan for the physical security of the individual site

CUP (Conditional Use Permit)

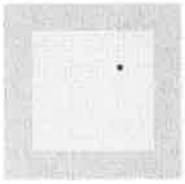
The WECS-C CUP **must comply with Section 15** within the Zoning Regulations in addition to the criteria laid out within these regulations.

Standard Conditions

includes, but not limited to:

- Limitation on future subdividing of land
- An annual report detailing the monthly power generated by each WECS-C
- Continually comply with U.S. Fish and Wildlife Service Land Based Wind Energy Guidelines
- All WECS-C shall be equipped with an automatic fire suppression system that meets the applicable NFPA standard or is otherwise approved by the fire district with jurisdiction.

Failure to Perform



WECOD

The County Commission shall have the authority, after a public hearing, to remove the WECOD if it determines that no WECS-C have been constructed in the District within a period of **ten (10) years** from the date of the County Commission Order that established the WECOD.

CUP

Any approved conditional use permit should be utilized within **one (1) year** of approval by the County Commission.

An invalidated permit can only be renewed by reapplication and approval as outlined within Section 15 of the Zoning Regulations.

If an applicant fails to meet **any** of the criteria outlined within the regulations, then the application shall fail. Whether or not an application meets all requirements is ultimately the decision of the County Commission.

Thank you

Events to follow:

Public Hearing – **Columbia**, Tuesday July 27, 2021

Public Meeting – **Ashland**, Wednesday, August 11, 2021

Public Meeting – **Harrisburg**, Tuesday, Aug 24, 2021

Consideration of amendment adoption to occur at a later date.

More information can be found on the Boone County website

www.showmeboone.com/resource-management/WECOD

You can also find:

- Links to the draft Regulations
- Copy of this presentation
- Wind Farm Frequently Asked Questions

Wind Farm Frequently Asked Questions

For official definitions of the following terms, please review the proposed or existing regulations.

WECOD: Wind Energy Conversion Overlay District
WECS-C: Wind Energy Conversion Systems – Commercial (aka wind turbine)

What is an "Overlay District"?
A regulatory tool that layers on top of an existing zoning district. The Overlay District modifies or supplements the regulations of the base zoning district to address special circumstances. The effect is to create a special zoning district which is placed over, and in addition to, the existing zoning.

What is a Conditional Use Permit?
A permit granted by the County Commission to allow a conditional use to occur on a specific lot.

The regulations mention "sections" and "quarter-sections" What does this mean?
Between 1815 and 1855, Missouri was surveyed into one-mile squares called sections; each section contains 640 acres. Quarter-sections are 1/4 (one-fourth) of a section containing 160 acres.

What is a Primary District in relation to a WECOD?
This is the area wind turbines may be located in. It's based on location of property proposing to establish a Wind Farm. The minimum size is 640 Acres (4 contiguous Quarter-Sections).

What is a Buffer?
A Buffer, as it relates to a Wind Energy Conversion Overlay District, is the area surrounding a Primary District and must be 1,320 feet outward (1/4 mile) around the entire Primary District. No wind turbines may be placed in the buffer area.

What happens when a wind farm is no longer commercially viable?
The owner is required to submit a Decommissioning and Land Reclamation Plan as part of the WECOD application. The owner is also required to provide financial security, in a form approved by the County Commission, that will ensure that money is available to implement the Decommissioning and Land Reclamation Plan.

Has the Boone County Resource Management office received any applications for commercial scale wind farms?
As of 7/26/2021: No

Is a wind farm, a WECS-C, and a turbine all the same thing?
WECS-C is the technical term used for a commercial turbine. The proposed regulations discuss "Clusters" of WECS-C's and this is synonymous with wind farms. (i.e. multiple turbines)

If someone attempted to build a wind farm right now, what would happen?
A commercial scale wind turbine is currently only allowed within Industrial zoning districts. Assuming that a turbine of this nature would be rather tall, then there would be an additional foot of setback for every foot the structure is above 45' tall. (i.e. 245' tall structure would have an additional 200' of setback in all directions from the standard setback requirements.) Any structure over 100' tall also requires a Conditional Use Permit subject to the approval of the County Commission

Do the proposed regulations limit the use of residential windmills for power generation?
No. Residential windmills (identified in the draft regulations as WECS-S) are currently allowed as an Accessory Use in Agriculture and Residential zoning districts. The proposed regulations only address windmills proposed for commercial power generation.

How does all of this affect the property owners?
If the proposed regulations are passed, there will be a "path" for commercial wind operations to apply to the County Commission for an Overlay District and then Conditional Use Permits for each WECS-C.
Before the application can be submitted, the property owner would need to submit a petition to the Director of Resource Management which would include a required super majority of neighbor's signatures in the proposed primary and buffer areas. If the neighbors do not feel the project is appropriate for their area, they would be able to reflect this through not signing the petition for application & the process would not move forward. However, if the neighbors *do* feel this is an appropriate use of the land then the opposite is true as well & the project can go through the application process.

What happens next?
There are 3 meetings scheduled:
Public Hearing – **Columbia**, Tuesday July 27, 2021
Public Meeting – **Ashland**, Wednesday, August 11, 2021
Public Meeting – **Harrisburg**, Tuesday, Aug 24, 2021

Consideration of adopting amendments to occur at a later date.
The County Commission will continue to review the proposed regulations after all above said meetings occur and a date has not been established for when WECOD Regulations will be up for a vote.

For more information and any updates please refer back to the dedicated Boone County Wind Farm Website: www.showmeboone.com/resource-management/WECOD

July 26, 2021

Boone County Commission
801 E. Walnut St.
Columbia, Missouri

Re: Proposed Wind Energy Conversion Overlay District Regulations

Dear Presiding Commissioner Atwill, Commissioner Aldred, and CommissionerThompson:

The American Clean Power Association (ACP) appreciates the opportunity to provide additional comments on the proposed wind energy regulations. As stated in our letter to the Planning and Zoning Commission on April 26, 2021, the restrictive nature of the Wind Energy Conversion Overlay District (WECOD) regulations will make it functionally impossible to build a wind farm in the county, placing current and future development opportunities for Boone County farmers and small businesses in jeopardy. We urge you to consider our below recommendations as you evaluate adopting the proposed WECOD for Boone County.

ACP is a national trade association representing a broad range of businesses in clean energy, including wind. The wind energy industry has a long track record of success across the United States, including Missouri. Nationwide there are 171,415 megawatts (MW) of operating wind, solar, and storage capacity, that supports 300,000 clean energy jobs. In 2020, clean energy provided an estimated $1.5 billion in local communities across the U.S. through state and local property taxes, and provided an estimated $1.1 billion to U.S. farmers, ranchers, and other private landowners in the form of lease payments.[1]

Missouri has approximately 1,266 MW of operating clean energy capacity and a combined clean energy workforce of 3,200. In 2020, clean energy provided an estimated $8.2 million in state and local property taxes, and approximately $13 million in lease payments to private landowners.[2]

To continue to expand the environmental and economic benefits provided by wind energy to Missouri and Boone County, there needs to be a reasonable pathway to securing project permits. The current draft WECOD, however, does not provide such

[1] American Clean Power Association (ACP). United States Fact Sheets. https://cleanpower.org/facts/state-fact-sheets/

[2] ACP. Missouri Clean Energy Fact Sheet. https://cleanpower.org/wp-content/uploads/2021/01/Missouri-clean-energy-factsheet.pdf

a pathway. We address some of the more restrictive components of the draft regulations below, including areas of overlap with state and federal authority, visual impacts, safety and setbacks, shadow flicker, sound, height restrictions, and decommissioning.

Definitions

"Furling" – This term is not commonly included in wind energy ordinances. It is unclear why this is included. If "furling" is interpreted by the county as pitch control, it should be noted that all modern turbines are pitch controlled; therefore, this inclusion is unnecessary and could be misinterpreted.

"Ice Throw" – The definition is misleading. An ice throw event is rare, and to date, no member of the public has been injured by an ice fragment released from a wind turbine blade and no structure has been impacted by an ice fragment. Turbines are equipped with sensors that recognize turbine blade icing, which triggers the shutdown of the turbine thereby stopping the blades from spinning. The data acquisition systems make it possible to analyze why a turbine shuts down, for example, or what may lead to one type of turbine failure or another. This analysis will lead to further improvements in operation and maintenance to maximize wind power output, as well a further reduction in what are already rare occurrences.

"Shadow Flicker" – The shadow flicker definition in the proposed regulations is too broad and misleading. Shadow flicker occurs when rotating wind turbine blades pass between the sun and an individual's home or occupied structure, casting a periodic shadow that may result in a flickering phenomenon. Shadow flicker cumulatively only occurs for a few hours per year and is more common around sunrise and sunset when the sun is low on the horizon resulting in longer shadows from the blades. There are many factors that influence duration and intensity of the shadows. ACP developed a shadow flicker factsheet[3] that provides additional information and recommendations that reasonably balance community and industry interests. The definition as written could result in unnecessary restrictions on landowners' properties, precluding landowners and residents who wish to install wind turbines from entering into agreements with a wind energy developer.

"Visual Dominance Zone" – The inclusion of this definition is problematic and adds an additional, overly burdensome "setback." It is unclear what criteria the county used to define "perceived as dominating the visual landscape," as perception is subjective, and what criteria was used to establish a visual setback of twenty (20) times the total height of the turbine. The establishment of this zone sets overly

[3] ACP. Wind Turbines and Shadow Flicker: Facts and Proven Mitigation Strategies. November 2020. https://cleanpower.org/wp-content/uploads/2021/02/Final_Shadow-Flicker-Fact-Sheet.pdf.

restrictive setback distances in addition to the Buffer Area Requirements established in Section 29.3.1.2 and the Safety Setbacks established in Section 29.8.6. of the proposed regulations. Establishment of multiple layers of setbacks would eliminate wind energy development in the county and unnecessarily restrict landowners and residents who wish to install wind turbines on their land.

"Well Designed Braking System" – The inclusion of this definition in the proposed siting regulations is unclear as is the criteria by which the county developed this definition and determined what defines "well designed." All commercially used wind turbines include braking systems designed by world-class engineers employed by the original equipment manufacturers, so this definition is unnecessary.

Intent and Purpose

Section 29.1.2 –Inclusion of this provision is unclear since wind farms are typically built-in agricultural areas on large, rural properties. Additionally, the use of "reasonably assumable future land uses" is too broad and it is unclear what the county considers reasonably assumable. Broad interpretation of this provision could result in the exclusion of large parts of the county from wind energy development, unnecessarily impeding wind energy development and disproportionately restricting landowners and residents who wish to install wind turbines on their land now in favor of some imagined future use opportunity which may never materialize.

Buffer Area Requirements

Section 29.3.1.2 – The reason for establishment of a buffer area in addition to the safety setbacks identified in Section 29.8.6 is unclear. Setback requirements are designed to protect a wind turbine's neighbors in the rare event of a tower failure, blade failure, or ice shedding from a blade while it is spinning; therefore, the addition of a 1,320-foot buffer area is duplicative of the safety setbacks, overly restrictive, and only serves to hinder wind development.

Natural and Biological Resources, and Historical, Cultural, and Archaeological Resources

Sections 29.7.2 and 29.7.5 requires an analysis of potential impacts of the project site to wildlife and vegetation, cultural, historical, and architectural resources, and landmarks with historic, religious, archaeological, scenic, natural, or other cultural significance; however, it is unclear the county's authority to regulate these resources and the process by which the county consults with the federal and state regulatory agencies that oversee the permitting process if impacts to these resources are identified. For example, the U.S. Army Corps of Engineers is responsible for review and permitting impacts to waters of the U.S. under Section

404 of the Clean Water Act, including wetlands and aquatic vegetation associated with wetlands; the U.S. Fish and Wildlife oversees the permitting process under the Endangered Species Act and the Bald and Golden Eagle Protection Act; Missouri's Department of Natural Resources oversees potential impacts to State listed threatened and endangered species and waters of the State. The Missouri State Historic Preservation Office reviews impacts to historic resources under Section 106 of the National Historic Preservation Act. Section 106 is only triggered by a federal action. The inclusion of prescriptive and duplicative processes would result in unnecessary, overly burdensome restrictions to project siting and development timelines.

Visual Impacts

Section 29.5.1.8 states that a visual simulation prepared by a "County approved third-party" is required; however, it is unclear the county's approval process and selection criteria for approving a third-party consultant. Unless a county has already established a list of county-approved qualified consultants from which a developer can choose, a project developer typically selects a qualified consult through a "request for proposal (RFP)" process.

This provision also states that the visual simulations should also include an analysis of "Any government-designated scenic byways, government-designated scenic overlooks, public parks, Conservation Areas, and Wildlife Refuges from which the project is readily visible as determined by the Resource Management Department in consultation with the applicant." "Any government" is ambiguous and misleading of the regulatory authority over these resources. Federal and state agencies such as the Department of Transportation, Wildlife agencies, and National Park Service have the regulatory authority over the official designation of and impacts to these resources. It is unclear the county's authority to designate and regulate these resources. Broad interpretation of this provision could result in the exclusion of wind energy development in the county and unnecessarily restrict landowners and residents from installing wind turbines on their land.

The criteria for determining the project requirements around minimizing "visual clutter," creating "visual unity," and avoiding "objectional density" in Section 29.7.3 is unclear. The use of vague and subjective measures in determining potential impacts is problematic and may result in broad interpretation of the regulations.

Sound

Section 29.8.2.1 requires a sound study to be conducted by "an acoustical engineer or other qualified professional as approvedby the Director of Resource Management"; however, it is unclear the county's approval process and selection

criteria for approving a qualified professional. Unless a county has already established a list of county-approved qualified acoustical engineers or qualified professionals from which a developer can choose, a project developer typically selects a qualified consult through a "request for proposal (RFP)" process.

This section also states "...to demonstrate that the system does not exceed an adjusted total day- night sound exposure (Ldn) of 45 measured from the property line." This statement is problematic as "adjusted" can be interpreted in several ways and the purpose of the Ldn based limit is unclear given the 50 dBA daytime and 40 dBA nighttime limitations identified in Section 29.8.2.2. Additionally, the limitations set forth in this provision at a property line are problematic. Typically, sound limits are applied to the nearest dwelling or occupied structure, as people are likely to spend more time in their house than standing on their property line.

"Sound exposure" is unclear and could be misinterpreted. There should be clarification to mean sound level attributable to the project. For example, on a windy day or just normal ambient, one may find that without turbines the sound exposure is 45 Ldn because of interpretation of the measurement, as stated above.

Sound and Health

Peer-reviewed, scientific evidence overwhelmingly finds that properly sited wind turbines do not harm human health. The credible, scientific peer-reviewed literature on this subject is expansive (more than 80 studies worldwide). Health Canada (the Canadian equivalent of the U.S. Department of Health and Human Services) and Statistics Canada published the most comprehensive multi-disciplinary field study to date (including surveys and objective health measurements), which found that self-reported sleep issues, illnesses and stress were "not found to be associated with WTN [wind turbine noise] exposure."[4]

With respect to objective health measurements, Health Canada and Statistics Canada found, "WTN was not observed to be related to hair cortisol concentrations, blood pressure, resting heart rate or measured sleep (e.g., sleep latency, awakenings, sleep efficiency) following the application of multiple regression models."[5] Health Canada's findings were also published in Environmental Research, a professional peer reviewed journal.[6]

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[4] Health Canada. Wind Turbine Noise and Health Study: Summary of Results. https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/everyday-things-emit-radiation/wind-turbine-noise/wind-turbine-noise-health-study-summary-results.html.

[5] Ibid.

[6] Feder, K., Michaud, D. S., Keith, S. E., Voicescu, S. A., Marro, L., Than, J., Guay, M., Bower, T.J., Whelan, C., van den Berg, F. (2015). An assessment of quality of life using the WHOQOL-BREF among participants living in the vicinity of wind turbines. Environmental Research, 142, 227–238. http://doi.org/10.1016/j.envres.2015.06.043

A 2019 joint research paper from the Environmental Health Sciences Research Center at the University of Iowa College of Public Health, Iowa Policy Project, and the Iowa Environmental Council[7] similarly resulted in the following key findings:

- "To date, no peer reviewed scientific journal articles demonstrate a causal link between people living in proximity to modern wind turbines, the noise (audible, low frequency noise, or infrasound) they emit and resulting physiological health effects ..."
- "Given the evidence and confounding factors, and the well-documented negative health and environmental impacts of power produced with fossil fuels, we conclude that development of electricity from wind is a benefit to the environment. We have not seen evidence that wind turbines pose a threat to neighbors. We conclude that wind energy should result in a net positive benefit to human health."

In 2014, the Massachusetts Institute of Technology (MIT) issued a comprehensive review of scientific literature on wind turbines and human health titled "Wind Turbines and Health: A Critical Review of the Scientific Literature." The peer reviewed report prepared by a multidisciplinary team with expertise in environmental medicine, epidemiology, acoustics, otolaryngology, clinical psychology, and public health was published online in the *Journal of Environmental and Occupational Medicine*.[8] The report included a literature review of over 160 references. The findings, summarized below, are consistent with the findings of other epidemiological studies related to wind and health, including the Health Canada study:

- Measurements of low-frequency sound, infrasound, tonal sound emission, and amplitude-modulated sound show that infrasound is emitted by wind turbines. The levels of infrasound at customary distances to homes are typically well below audibility thresholds.
- No cohort or case–control studies were in this updated review of the peer-reviewed literature. Nevertheless, among the cross-sectional studies of better

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[7] Thorne, Peter S., Osterberg, David, and Johannsen, Kerri. Wind Turbines and Health. https://www.iowapolicyproject.org/2019docs/190131-Wind-Health.pdf.

[8] McCunney, Robert J. MD, MPH; Mundt, Kenneth A. PhD; Colby, W. David MD; Dobie, Robert MD; Kaliski, Kenneth BE, PE; Blais, Mark PsyD. Wind Turbines and Health: A Critical Review of the Scientific Literature. Journal of Occupational and Environmental Medicine: November 2014 - Volume 56 - Issue 11 - p e108-e130. Available online at: http://journals.lww.com/joem/Fulltext/2014/11000/Wind_Turbines_and_Health_A_Critical_Review_of_the.9.aspx.

quality, no clear or consistent association is seen between wind turbine noise and any reported disease or other indicator of harm to human health.
- Components of wind turbine sound, including infrasound and low frequency sound, have not been shown to present unique health risks to people living near wind turbines.

Annoyance associated with living near wind turbines is a complex phenomenon related to personal factors. Noise from turbines plays a minor role in comparison with other factors in leading people to report annoyance in the context of wind turbines.

Safety Setbacks

Wind turbines consist of rugged but also sophisticated equipment, and operate under high wind conditions, subject to constant motion and sometimes challenging environments. Given these challenging operating conditions, wind turbines are remarkably reliable. Turbines are equipped with sensors and data acquisition systems that make it possible to analyze why a turbine shuts down or what may lead to one type of turbine failure or another. Wind companies manage this risk through detailed study and analysis, careful engineering, and cautious standard operating procedures.

As stated previously, setback requirements are designed to protect a wind turbine's neighbors in the rare event of a tower failure, blade failure, or ice shedding from a blade while it is spinning. There are more than 60,000 utility-scale wind turbines operating across the United States with blade or tower failures limited to just a few incidents in any given year. To date, there has not been one report of injury to a member of the public or a blade or ice fragment impacting a neighboring residence or structure.

A setback equal to or slightly greater than the total tower height is common and accepted practice across jurisdictions in the United States with successfully operating wind projects. There is currently no evidence to support any additional public safety benefit from longer setback requirements like the one proposed in Section 29.8.6.1 of the regulations (1,750 feet). A setback requirement of 1,750 feet would unnecessarily impede wind energy development in the county and restrict landowners from installing wind turbines on their land. In addition, as stated above, the proposed regulations impose a "visual dominance zone" setback of 20 times the total turbine height and a buffer area requirement of 1,320 feet from the wind conversion overlay district. As interpreted, a wind project would potentially be subject to setback requirements ranging from 1,750 feet to 11,070 feet – more than

two miles (assuming a total turbine height of 400 feet), which would essentially ban wind turbines in the county.

Fire Safety

Although uncommon, fires can occur due to various reasons, including lightning strikes or short circuiting. Photos of these incidents can seem alarming, but the fires are quickly contained. Wind turbines are continuously monitored by numerous sensors and data acquisition systems that detect when there is a system failure. The sensors make it possible to analyze why a turbine shuts down, for example, or what may lead to one type of turbine failure or another. Additionally, wind turbines go through regular inspection and maintenance during the life of the project.

Smoke or fire alarm systems work in a way that detects fire through smoke, heat, flame, or gas combustion – depending on the system. Typical fire suppression systems are designed to suppress fires in various sources – isolation of the fuel, reduction of temperature, reduction of oxidizing agent (oxygen), or breaking the reaction. Given the nature of the wind turbine, there is not a one size fits all solution that would ensure that a fire would be suppressed in all possible conditions. Given the nature of the wind turbine design, many of the systems and options are limited (with the openings, joints, and rotating parts). In certain cases, a system would put the workers at a high risk and impact their safety and health.

There are several passive fire protection practices such as various engineering solutions:

- Continuous condition monitoring systems (CMS): Continuous CMS are standard within the industry. The health of the wind turbine and wind plant site is essential for optimal efficiency and reliability for the operation of a wind energy.
- Standards that design for comprehensive protection systems that include lightning and fire protection:
    - IEC 61400-1
    - IEC 61400-24
    - IEC 61400-30
    - NFPA 850, 780 and 70
- Use of different non-combustible hydraulic and lubricant oil.
- Use of flame retardant materials.

Maximum Turbine Height

The proposed regulations impose a maximum total turbine height restriction of 355 feet with a case-by-case allowance of 400 feet; however, technology innovations from the U.S. Department of Energy, other research institutions, and industry have

allowed wind turbine hub heights and sizes of blades to grow and increase energy production.[9] As technology advances and industry innovation grows, it is important that regulatory frameworks allow for flexibility. In 2019, the average utility-scale wind turbine had a nameplate capacity of 2.55 MW. The average rotor diameter was 121 meters (397 feet), and the average hub height was 90 meters (295 feet)[10], resulting in an average total height of 493 feet. As of 2021, the median height of all operating wind turbines in the United States is 420 feet.[11] The maximum height restriction of 355 to 400 feet would restrict wind development in the county as it may not be feasible or economical to use smaller turbines. In fact, such a restriction may be counter-productive to the County, as it could force a developer to deploy more, but less-efficient turbines, creating more potential visual disturbance which the ordinance itself claims to want to avoid.

In 2019, utility-scale wind turbines were reaching 499 feet or taller, with many commercial wind turbines reaching 695 feet by 2021.[12] Taller wind turbines are more efficient, making it possible to cost-effectively capture the stronger wind resources at higher levels; therefore, fewer turbines are needed on the landscape. Needlessly restricting turbine height to decade-old and outdated technologies not only thwarts the innovations achieved in the industry but also would negatively impact reliability and cost-savings benefits achieved by a the constantly innovating clean power sector. Industry practice is to provide cost-effective clean energy that results in lower prices to the consumer.

Lighting

Section 29.8.6.5 indications that "lighting of turbines shall be radar activated and in compliance with the FAA [Federal Aviation Administration] Aircraft Detection Lighting System regulations." For aviation detection lighting systems (ADLS), the FAA requires the lighting be activated and flashing if an aircraft is at or below 1,000 feet above the tallest wind turbine and is approaching a three-statute mile (SM; 4.8 kilometers) perimeter around the project. Although the FAA's guidance has been published and ADLS vendors have been certified, this does not mean ADLS can automatically be installed on a project. For each project that is considering using ADLS, a request must be made to the FAA, and the FAA evaluates each request on a

[9] Department of Energy, Wind Energy Technologies Office. https://www.energy.gov/eere/wind/articles/wind-energy-grows

[10] Lawrence Berkeley Lab. Wind Energy Technology Data Update: 2020 Edition. Slide 36. https://emp.lbl.gov/sites/default/files/2020_wind_energy_technology_data_update.pdf

[11] US Wind Turbine Database Version USWTDB V4.0. https://eta-publications.lbl.gov/sites/default/files/uswtdb_v4_0_20210409_memo.pdf

[12] Ibid.

turbine-by-turbine basis.[13] The FAA can deny the ADLS usage on certain turbines due to proximity to airports, low-altitude flight routes, military training areas, or other areas of frequent activity. As a result, the county should allow developers the flexibility to work through the feasibility of such systems on wind farms with the FAA. For wind turbines to comply with FAA determinations and to ensure the safety of the National Airspace System, marking and lighting must be installed in compliance with FAA's conditions and guidance.

Decommissioning

In 2020, ACP published wind industry recommendations[14] for key provisions of decommissioning plans / rules, including specific measures that reasonably balance community and industry interests. We encourage the planning commissioners to review the industry recommendations specifically, the recommended financial assurance (security) and timing provisions.

Conclusion

It is important to note that the Lawrence Berkeley National Laboratory (LBNL) survey, the largest, most comprehensive study of its kind in the United States, found that: (1) fewer Americans than Europeans say they can hear the wind farm outside their home and fewer report being strongly annoyed by turbine sound; and (2) if a person was opposed to the project during the development phase, that person was more likely to report being able to hear the turbines and be annoyed by the noise. The LBNL study also found that, on average, most residents (92 percent) near wind projects had positive-leaning attitudes towards the wind project. The study found the positive attitudes tended to improve over time as individuals self-select into communities near existing wind projects. [15]

Overall, wind energy developers have good success at being responsible community members and business partners in Missouri and throughout the U.S. As the facilities they construct will be operating for 30+ years, our members recognize the need for extensive public engagement to fully address community concern to the greatest extent possible. We strongly urge you to engage with the wind energy industry to understand what types of requirements strike a balance that allows development to move forward while still protecting the interests of the community. We appreciate

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[13] FAA Advisory Circular 70/7460-1M, last updated November 16, 2020. Chapter 13 is specific to lighting and marking of wind turbines. https://www.faa.gov/documentLibrary/media/Advisory_Circular/Advisory_Circular_70_7460_1M.pdf.

[14] ACP, Wind Project Decommissioning: Industry Recommendations. https://cleanpower.org/wp-content/uploads/2021/01/Decommissioning-Fact-Sheet.pdf

[15] Hoen, Ben, Jeremy Firestone, Joseph Rand, Debi Elliott, Gundula Hübner, Johannes Pohl, Ryan H Wiser, Eric Lantz, Ryan Haac, and Ken Kaliski. "Attitudes of U.S. Wind Turbine Neighbors: Analysis of a Nationwide Survey." Energy Policy 134 (2019).

the opportunity to provide comments on the proposed regulations. Thank you for your consideration of the issues raised.

Sincerely,

Hilary Clark
Director, Social License

Jeff Danielson
Central Region Director, State Affairs

Daniel Hall
Central Region Director, Electricity & Transmission

Hello my name is Kendra Talbert. My husband and I live on an 80-acre Farm in Northeast Missouri, with our three kids. Our oldest, Warren, will be 15 in December, and has nonverbal autism. Our twin daughters, Avril and Vaden, will be 11 in September. They are also on the Spectrum and would have a PDD NOS diagnosis if there were still different classifications. I'll start with a short back story. Warren was born in 2006. Everything was typical, typical pregnancy, typical birth, and typical happy/healthy baby. At 3m, we noticed things were off. At 6m, it was more noticeable. At 18m, we visited Dr. Stroud at the Thompson Center, here in Columbia. When I say Warren was "off", I mean, he didnt make eye contact, he didnt really react to facial expressions, he had like 6 words. After exhausting evaluations, they determined he had some autistic tendencies, but due to his age, advised us to wait until he was a little older and if we still had concerns to come back. We recieved his official diagnosis at age 3 and it's been years of intense therapy ever since. I'm not gonna go into all the different therapy's and avenues and trainings that we've done and continue to do and he ages. For those that dont know, it's mentally, physically, emotionally, exhausting and draining!! I only want what's best for my kids, as all parents should. Warren's happiness is instrumental in how our family runs. If he's upset, it effects EVERYTHING!! With him being nonverbal, his actions and behaviors are what we watch to determine what the "problem" may be.

Last year, the Wind Turbine project was brought to my attention. We had been contacted and offered a turbine a year prior. We chose not to get one for 2 reasons. 1) we didnt work, suffer, and sacrifice to buy our farm, to destroy it with a turbine. 2) we didnt know how it would effect Warren. We heard nothing more from the turbine reps or the county about the project going ahead. So when I found out that the county was going ahead with the project I was shocked. I started researching all the effects of turbines on autistic children. Every autistic person is different and because of that I didn't know how the turbines would affect Warren. But I did know that there would be nothing I could do about it after they were constructed. I approached the Commissioners in the zoning board with some data that I had found about other family's experiences with turbines and their autistic children. I asked for further setbacks from my property line. There were two of the turbines going to be less than a mile from my property line and two turbines going to be just a little over a mile from my property line. I asked that the turbines and or transmission lines to be set back at least a mile from my property line. I had a meeting with one of the Commissioners and one of the representatives from the turbine project. I voiced my concerns about my son. They both understood and agreed that yes once the project was complete and I found out that there was issues that really there was nothing I can do to get the turbine taken down. They asked me about the two turbines that we're under a mile from my property line. Of the two they asked if the farthest one could stay if they can maybe do something about the one that was the closest. We stated that the one that was the closest was definitely the one that we were most concerned about we were not sure about the one that was second closest. I later found out through an outside source that the turbine that was in question was now being scrapped and they were going to use the alternate location. But the second closest turbine would remain. Warren went from being a kid. Was outside all the time. You would hear the door slam at 9 at night and he would be outside jumping on the trampoline. He was either swimming swinging jumping on the trampoline playing outside with the dogs whatever he can do outside whenever he could be outside and that's where he was. As soon as the truck started rolling in with all the equipment we started noticing that he wouldn't come outside. Then

when he was outside he would stand and hold his hands over his ears. We'd have to force him to come out and try to do something and when he when he did he we just scream and cry until we finally just let him go back in the house and then he would be fine. That was just when they were rolling the equipment in and doing dirt work. When they actually started the construction that's when it got really bad. That's when behaviors started happening that we had never ever seen before. And it only got worse the further the construction went. Now he absolutely detest being outside, even when the turbines are not running he hates it. The flashing life drive him crazy. He has to wear a jacket when he goes outside so he can put the hood over his face and shield his eyes from the flashing lights. When the blades are turning he has to Shield his eyes from the Turning blades. When they're actually running to the point you can hear them then he has to plug his ears. It is miserable for him at our house. And it breaks my heart to think that he is so miserable that he can't even go outside and do the things that he absolutely love to do before. One of his favorite things to do at school was to swing. The teacher said that when they asked if he wanted to go swing he would always tell them no. But they would make him go outside anyway and he would go and get underneath a piece of equipment to where he could not see the turbines and cover his eyes and cover his ears and set underneath it until they were ready to go back in. He lives a life of misery oh, because of the turbines. So in turn my husband and I and his sisters live a life of misery also. This is just my experience, I'm here to share what we have gone through. It is going to take numerous extra hours and dollars for therapy to try to just get him back to where he was before this whole thing started. I'm not saying every family is going to be like that but I would hate for anybody to take that chance. About four months ago I ran into a gentleman that had been a representative 4 wind turbines. He was the one that went around and sold people on getting one. I overheard him talking about it and I started asking him questions and I told him my situation. He told me he was glad that he didn't work for a wind turbine company anymore. And that there is actually an "autism clause" that states no turbines within 1 mile of all property lines of autism families. I hope my story helps someone and reaches ears that need to hear it.

kendrajo1979@gmail.com

Zack Dunn
Director of Government Affairs
Missouri and Kansas Laborers District Council

June 27, 2021

I want to thank the commissioners for holding public hearings and for the work they are doing on this issue. My name is Zack Dunn. I am a resident of Columbia, and I have the pleasure of serving as the Director of Government Affairs for the Missouri and Kansas Laborers District Council. Our organization represents more than 200 members in Boone County. On the behalf of our members, I would like to provide input to the commissioners and seek three fundamental changes to the proposed WECOD regulations.

In 2018 our international union conducted a study on the impact windfarm local hiring practices had on communities in Minnesota. Much like Missouri is today, Minnesota was experiencing a flux of wind development across the state. Developers were bringing work crews from other states to complete the construction. Out of state work crews would often receive a per diem of $100 a day. That per diem would be the only money they spent while working on a project. When the project was complete, the workers left for different parts of the country taking their wages with them. Local workers, in comparison, live in the communities near the wind projects, and will spend their wages at local businesses, hospitals, and pay various taxes. This resulted in just one local worker contributing $40,000 more to their local community when compared to the out of state transient worker. When you compare projects that secured local hire commitments to ones that did not, the communities with local hire commitments received tens of millions of dollars more in local economic activity and tax revenue. We believe the commissioners should add local hire language that seeks commitments from developers, contractors, and subcontractors who apply for a WECOD permit. This provision would support local workers, local businesses, and our overall local community.

In addition to local hire provisions, we believe the commission should add to existing language to establish an apprenticeship program requirement. Department of Labor registered apprenticeship programs help create careers in construction and provide a highly trained workforce. Contractors who bring on an apprentice provide on the job learning and a guarantee the apprentice will have a position on their crew beyond the current project. This ensures new construction workers have a career rather than finish a project and go on an unemployment list. Additionally, contractors and subcontractors responsible for the construction of wind farms will have a trained work crew who experience fewer workplace injuries and are trained to adhere to environmental best practices.

Finally, it is clear to us that as the regulations are written, they act as an outright ban on windfarm development within the county. This status quo would mean the loss of hundreds of jobs and millions in local economic spending and tax revenue. Whether we like transition to renewable energy or not, the change is inevitable. Boone County should be a leader for other communities across the state and for the workers and businesses in our community.

I thank the Commissioners for their time and their consideration this evening.

Laborers Local 955
404 Tiger Lane
Columbia, MO 65203

26 July 2021

Boone County Commission
Daniel Atwill, Presiding Commissioner
Janet Thompson, Commissioner
Justin Aldred, Commissioner

Re: Proposed Boone County Wind Energy Conversion Overlay Regulations

Dear Board of Commissioners,

The Missouri and Kansas Laborers District Council and Laborers Local 955 represents over 200 members in Boone County. On the behalf of our members, Laborers Local 955 and the Missouri and Kansas Laborers District Council would like to submit input to the Boone County Commission and seek three fundamental changes to the proposed WECOD regulations.

The Laborers International Union has been on the forefront of studying the impacts of windfarm development on local communities. Most notably, in the state of Minnesota, we conducted a study to determine the impact local hire commitments had on local communities that were developing windfarms. We found that because non-local workers often receive a per diem, they will only spend their per diem in the community, and once the job is complete, they leave the area. This results in local workers spending on average $40,000 more in a year than a non-local worker in the community.[1] Large national and multinational developers frequently use transient work crews that will travel from job to job all over the country. Communities that do not seek local hire commitments in the permitting process will lose tens of millions of dollars in local spending and tax dollars. Boone County should adopt language that seeks to reach local hiring commitments from its developers, contractors, and sub-contractors.

Second, we have heard the concerns from community members about the safety and environmental impacts of large projects like a windfarm. One proven way to reduce safety and environmental concerns is through registered apprenticeship programs. Contractors and subcontractors that are a part of a Department of Labor registered apprenticeship program experience less workplace injuries.[2] This is because of the immense training to learn about the risks associated with the job, how to avoid those risks, and how to properly perform the job at hand. Additionally, many apprenticeship programs require classes that address issues like soil erosion or how to properly dispose of toxic waste. Safety and environmental concerns can be mitigated by a highly trained workforce.

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[1] Local spending differential between local and non-local workers can be found on table 3 in Catching the Wind 2.0. Study found here: https://d3ciwvs59ifrt8.cloudfront.net/19d28156-d283-4f19-aa25-a3a81dcfffdf/5d62076d-cfaa-4d0d-b4c2-82a55b767446.pdf

[2] "Investment in training and skill upgrading translates into fewer workplace injuries and fewer job interruptions." https://illinoisepi.org/site/wp-content/themes/hollow/docs/wages-labor-standards/pcmr-ilepi-impactofapprenticeshipprograms_newcover.pdf

Richard Fray
Boone County Commission Testimony
July 27, 2020

My name is Richard Fray, I live in Moberly, Missouri, and I am a proud member of Laborers Local 955 here in Columbia, MO. I am currently one of the workers building a wind farm in High Prairie. I am here today to share my experience working on a wind development and join my union in advocating for changes to the proposed regulations.

I have been working at the High Prairie wind farm for about a year now. My work has been erosion control, hauling and transporting, and various dirt work around the work site. This project has provided me good, consistent work, that has allowed me to earn a honest paycheck. There are a lot of guys that would love to work on a project like this if they were given the chance. From my experience in High Prairie much of the work crew is out of state. It is clear more needs to be done to ensure local workers have an opportunity to work on the wind farm developments that are happening around the state.

Boone County can seek local area hire commitments from developers applying for permits for wind farm developments. I support all efforts to secure those commitments. This allows workers like me to be a part of the transition to renewable energy and building wind turbines that the community can be proud of. Local area hire provisions also ensure money being paid to workers is being spent here in the communities we live in.

I joined my union because I wanted a good paying career, not just a job. Like any career, I had to go through training where I learned both in a classroom and on a job site. As an apprentice I learned how to safely and properly perform a wide variety of work. Not every guy on the high prairie worksite has the same level of training as me, and it shows. In addition to provisions seeking local hire commitments, I urge the commissioners to consider adding a department of labor recognized apprenticeship program partnership requirement to all contractors and subcontractors seeking work on a windfarm. This helps maintain the safety of workers and the safety of neighbors who rely on the wind turbines to be built properly.

Boone County can create hundreds of good paying construction jobs here in our communities. I would love an opportunity to work on a wind farm much closer to home. Based on testimony we have heard in the planning and zoning commission and here today, I am worried that the proposed regulations, as they are written, will prevent any wind farm project from ever being built. This would hurt our local businesses, our local governments, and most importantly our local workers. I ask you make changes necessary to provide working people an opportunity for a better living.

Thank you for the opportunity to be here today and thank you to the commissioners for sharing their time with me this evening.

Smaller Turbines Hold Up Better and with Less Health Effects

NIRTANA GOODMA · SUNDAY, 4 APRIL 2021 ·

"Dr Alan Watts of the Carcoar Medical Centre submitted that :

Small increases in the diameter of a wind turbine's rotor area can lead to substantial increases in the effects of wind speed (because the area of a circle is (πr² which thus results in an exponential increase in the production of sound waves (specifically infrasound or low frequency vibration). This is a problem with modern wind turbines where increasing size will potentially cause intensifying infrasound related health problems."
https://www.aph.gov.au/.../201.../impactruralwindfarms/index

The longer the turbine's blades, the more pressure is put on internal mechanisms. Shutterstock

Taller turbines generate more power, which puts greater loads on the gearbox and transmission system, requiring mechanical engineers to develop new ways of converting the ever-increasing torque into electrical power. Taller wind turbines also need stronger support towers and foundations. The list of challenges is long.

As turbines grow, so too does the noise they make. The dominant source of noise occurs at the outer edge of the blades. Here, turbulence caused by the blade itself creates a "hissing" sound as it passes over the trailing edge. More noise is created when the blade chops through atmospheric turbulence in the wind as it blows into the tower."
https://theconversation.com/taller-faster-better-stronger-wind-towers-are-only-getting-bigger-120492

https://www.power-technology.com/features/bigger-is-not-always-better-how-small-scale-wind-turbines-could-save-the-sector/

330–600+ feet high

Blades sweeping 1–2 acres vertical area, tip speed 150–200 mph

Dead birds and bats

Displaced ground animals

Noise and vibration

Hundreds of tons of concrete and steel in each foundation

Storm runoff, altered hydrology

Roads and transmission lines

Fragmented wildlife habitat

Shadow flicker

Strobe lights day and night

Visual intrusion and distraction

Degradation of social and natural environments

Misplaced public funds

Unreliable contracts

Unproven benefits

Learn more!

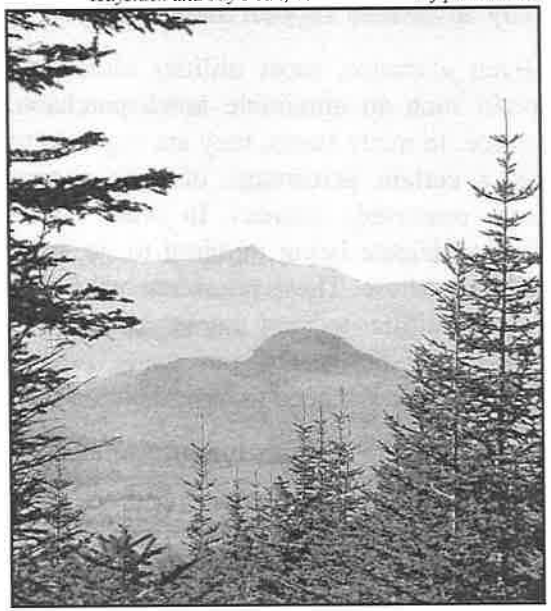
National Wind Watch

(www.wind-watch.org)

Industrial Wind Energy Opposition

(www.aweo.org)

Haystack and Jay Peak, Vermont. Used by permission.



SAY NO!

to destroying the environment and our communities

NO INDUSTRIAL WIND!

**New wind turbines are now over 600 feet in height.*

1. Audible sound
2. Inaudible sound and vibration/pulsation
3. Accompanying sleep deprivation that
4. May cause negative health issues.
5. Higher electricity rates
6. Loss of property value
7. Shadow flicker
8. Barely 35% efficient. Need back up fossil fuel plants that run constantly creating nothing but pollution.
9. Trespass Zoning (uncompensated easement without permission)
10. Miles and miles and miles of additional transmission lines above and below ground.
11. Red flashing warning lights
12. Weak or NO decommissioning language in wind ordinances that can result in eye sores for generations.
13. Oil leaks from wind turbine
14. Ice throw
15. Blade throw
16. Fire in the Nacelle
17. Wind turbine collapse
18. Stray/Induced Voltage
19. Possible damage to water in water wells depending on layout and location of wind turbine.
20. Aesthetics
21. Damage to wildlife, domestic and farm animals
22. Bird and BAT kills especially raptors
23. MASSIVE gov't handouts oil, nuclear, and natural gas don't receive anywhere near that amount.
24. Reduction in economic growth and expansion
25. Interference with emergency radio, tv, and cell phone reception.
26. Interferes with crop dusting
27. Mercy flight interference
28. Damaging to economy of tourist areas
29. Destruction of the social fabric in smaller communities
30. Toxic/radioactive pollution from mining rare earth minerals used in wind turbine magnets.
31. Interference with weather radar

PUBLIC HEALTH STATEMENT

Re:
Injunction Proceedings against High Prairie Wind Farm

by
Mariana Alves-Pereira, Ph.D.

August 5th, 2019

Brief Biographical Background
(Full *Curriculum Vitae* and *List of Publications* is included in Appendix 1 of this Statement.)

Mariana Alves-Pereira holds a B.Sc. in Physics (State University of New York at Stony Brook), a M.Sc. in Biomedical Engineering (Drexel University) and a Ph.D. in Environmental Sciences (New University of Lisbon). She joined the multidisciplinary research team investigating the biological response to infrasound and low frequency noise in 1988, and was the team's Assistant Coordinator from 1999 until 2015. Recipient of three scientific awards, and author and co-author of over 50 scientific publications (including peer-reviewed and conference presentations), Dr. Alves-Pereira is currently Associate Professor at Lusófona University (Lisbon, Portugal) having taught Biophysics and Biomaterials in health science programs (nursing and radiology), as well as Physics and Hygiene in workplace safety & health programs. Additionally, she now actively contributes to an International Consortium of Scientists investigating the health effects of infrasound and low frequency noise among human and animal populations, in both occupational and residential settings. Prof. Alves-Pereira is a U.S. citizen and can readily be reached at: m.alvespereira@gmail.com.

To the Presiding Judge,
Missouri Circuit Court

I respectfully request that my Statement be considered within these proceedings given the grave nature of Public Health issues that are at stake for the citizens of Schuyler (and Adair) counties.

1. Purpose of this Statement

On August 1, 2019, I received an email from Ms. Carrie March, of Queen City, MO, requesting that I submit this Statement, given my extensive expertise on the matter of the health effects caused by long-term exposure to *infrasound and low frequency noise*—a type of toxic pollutant that is generated by wind turbines.

2. Why is there an issue?

Under the current proposal for the High Prairie Wind Power Station (a.k.a. 'wind farm'), the home of Ms. Carrie March will be surrounded by 16 turbine towers within a 1.8-mile radius (approximately 3 km or 10 000 ft)[1]. (See Figs. 1 thru 3.)

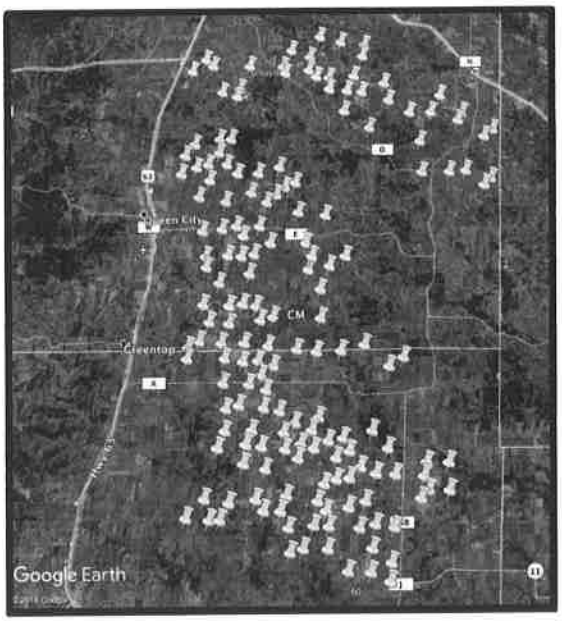


Figure 1. Google Earth image showing the proposed High Prairie Wind Power Station, with wind turbine towers in yellow and the home of Ms. Carrie March in red (CM). (North points upward.)

[1] A 3 km (1.8 mile) cutoff was decided upon for the presentation of this Statement to facilitate comparison with other (scientifically published) cases and that will also be presented herein.

Figure 2. Google Earth image showing a closer view of the wind turbine towers (yellow) and the home of Ms. Carrie March (red-CM).

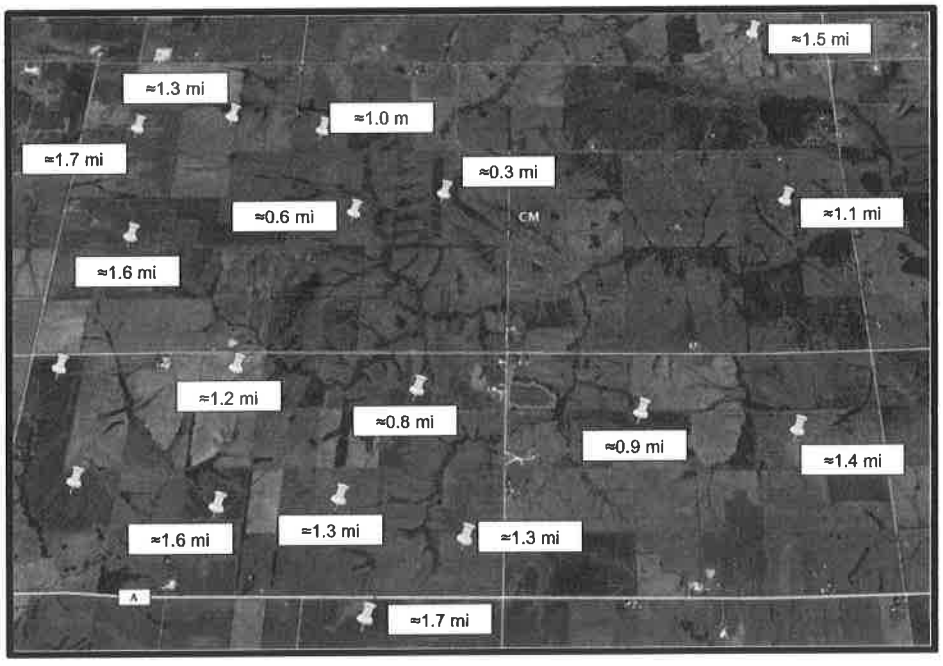


Figure 3. Google Earth image showing the turbine towers (yellow) located within ≈1.8 miles (≈ 3 km) from the Carrie March home (red-CM). (North points upward.)

3. What is this Toxic Pollutant?

Formally, it is called "infrasound and low frequency noise" (ILFN).
Typically, it comes under the category of 'noise' and / or 'non-ionizing radiation.'
In the Unites States, this type of 'noise' is not legislated.

4. What happens to people's health when this toxic pollutant is in their homes due to the close proximity of wind power stations?

It is a gradual process—not like a 'zapping' action. Initially, after wind power stations are fully commissioned near residential dwellings, families may not feel an immediate impact. This lulls them into a sense that "everything will be fine," and they remain within the toxic environment.

However, often within the first 5-7 months of exposure, family members will begin to wake up tired. They will begin to feel increasingly annoyed and more aggressive, particularly if there is a history of prior ILFN exposure (such as military duty, for example), or if family members are pubescent or pre-pubescent adolescents. In ILFN-contaminated homes, families *sleep in* the toxic environment, greatly accelerating the onset of debilitating disease.

Sleep deprivation and the likely development of brain lesions in the hippocampus (as seen in laboratorial experiments) and brainstem (as seen in exposed workers), begin to explain the cognitive impairment displayed by these individuals, sometimes accompanied by uncontrolled emotional states or transient absences of consciousness. As exposure time accumulates, increasingly disabling health conditions develop. These can comprise the respiratory and gastrointestinal systems, as well as the organs of vision and hearing. Since citizens are forced to remain in their homes under these toxic circumstances, severe and debilitating health deterioration is merely a question of time.

Until recently, the effects of ILFN on health were mostly investigated within the context of occupational settings. These studies were designed to investigate various types medical outcomes while simulating occupational exposures, i.e., large amounts of infrasound exposure during several hours per day. When ILFN is in the home, levels can be significantly lower than in occupational settings, but *exposure time is much longer and can occur during sleep-time*, i.e., the worker goes home (ceases exposure) at the end of the work-shift, but no such respite exists in situations of residential contamination.

Appendix 2 provides a Book Chapter[2] dedicated to this topic, as well as a Summary of the chapter for laypersons.

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[2] Alves-Pereira M, Rapley B, Bakker HHC, Summers R. (2019) Acoustics and Biological Structures, IN: Acoustics of Materials. Abiddine ZE, Ogam E (eds). IntechOpen, London. — Appendix 2
DOI: 10.5772/intechopen.82761. https://www.intechopen.com/online-first/acoustics-and-biological-structures

5. How could this possibly be true?
There would be sick people everywhere!

- **Case Report 1[3]: Ireland—Abandoned Home**

Figure 4 shows a home in Ireland that had to be abandoned given the onset of severely debilitating health issues (*ongoing legal proceedings*).

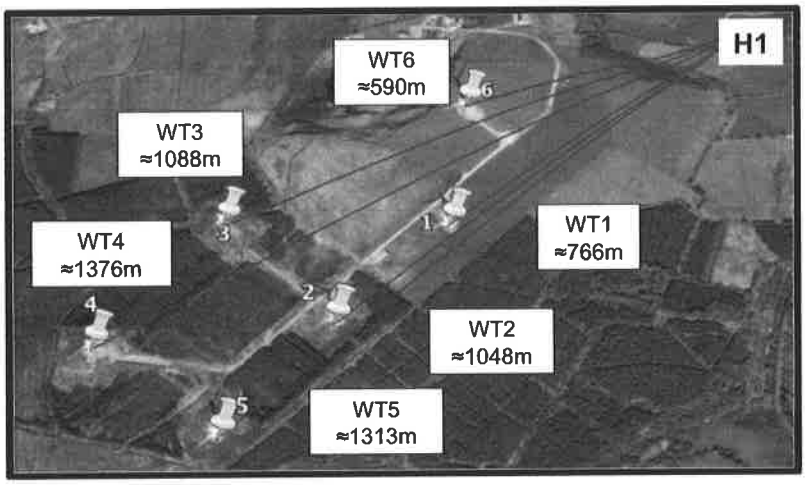

Figure 4. Google Earth image showing 6 wind turbine towers (yellow) located between ≈0.3 miles (590 m) and ≈0.8 miles (1376 m) from a residential dwelling (H1) —Ireland. (North points upward.)

Please note the reduced amount of wind turbines as compared to the Carrie March home (6 *versus* 16).
Also note that the 6 wind turbines in Ireland do not surround the home on all cardinal directions, contrary to what occurs with the March home which has turbine towers in practically all directions (see Fig 3).

In this home, the youngest child (age 7) was formally diagnosed with epilepsy. The oldest child (age 19) was formally diagnosed with post-traumatic stress disorder.

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[3] Alves-Pereira M, Bakker HHC, Rapley B, Summers R (2018). Infrasound and Low Frequency Noise – Does it affect human health? Engineers Ireland Journal, Jan 23. — Appendix 3.
http://www.engineersjournal.ie/2018/01/23/ilfn-infrasound-low-frequency-noise-turbine-health/

- **Case Report 2[4]: Germany—Abandoned Bedroom & Bunker Bedroom**

Figure 5 shows a home in Germany where 20 turbine towers were erected in the southern and eastern sides of the home (*ongoing legal proceedings*).

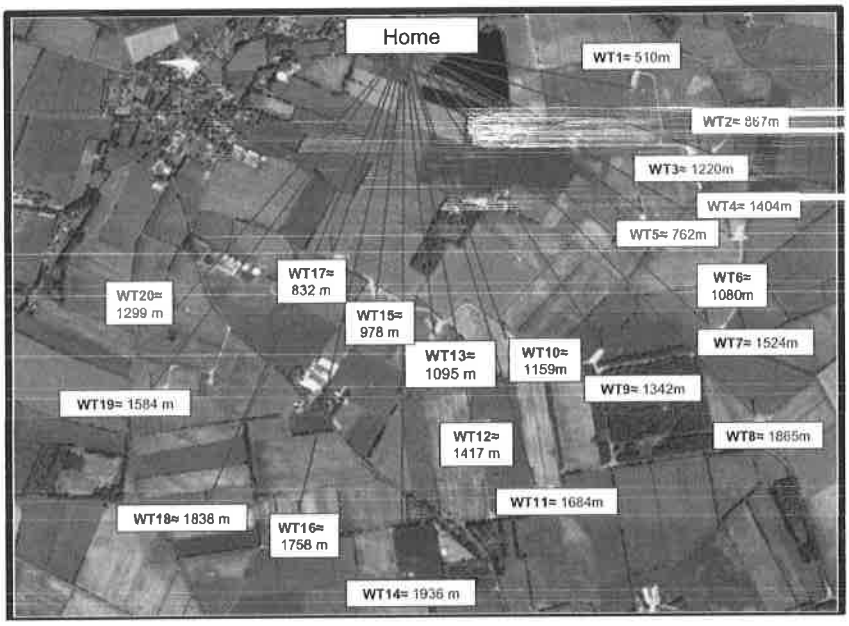


Figure 5. Google Earth image showing 20 wind turbine towers located between ≈0.3 and ≈1.2 miles (0.5—2 km) from a residential dwelling —Germany. (North points upward.)

Again, as with the Irish home, the turbine towers do not surround the home in all cardinal directions, although there is a slightly larger density of machines in this German case than in the March home.

These German homeowners develop their business at this location and are, therefore, unable to abandon their home. Their teenage children, however, were promptly sent away to boarding schools given their accelerated and very evident behavioral and metabolic changes. The health deterioration of this family has been documented in the German media (see Appendix 4).

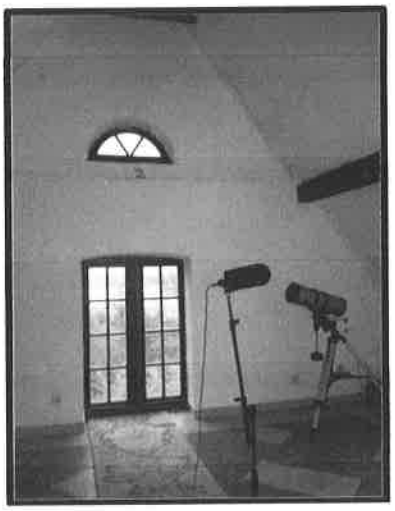
In order to be able to continue running their business, this German family was forced to abandon their master bedroom and construct an underground bunker so as to achieve some sort of respite against the aggression of this toxic pollutant. Figure 6 shows the abandoned and bunker bedrooms.

---

[4] Alves-Pereira M, Krough C, Bakker HHC, Summers R, Rapley B (2019) Infrasound and low frequency noise guidelines – Antiquated and irrelevant for protecting populations. Proceedings of the 26th International Congress on Sound & Vibration, Montreal, Canada, July 7-11, 2019—Peer-Reviewed Conference Paper. – Appendix 4

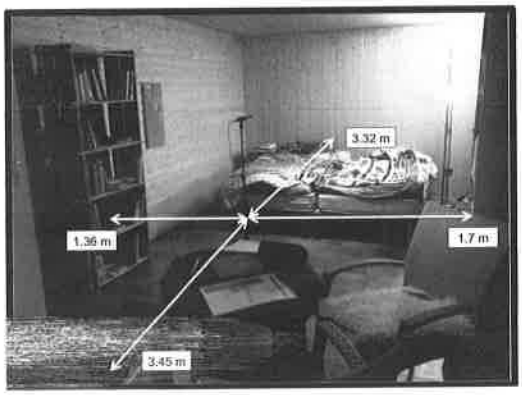
Figure 6.

A



(A)
The Master Bedroom facing East and overlooking the neighboring lake (see Fig. 5) — Abandoned due to ILFN contamination.

B



(B)
The Bunker Bedroom is built deep underneath the home, where respite from the toxic pollutant is achieved "except when the winds are from the East."

In the Bunker Bedroom, respite from the toxic pollutant is achieved "except when the winds are from the East." This is easily explained by looking at Figure 5, showing the towers closest to the home on the eastern side of the property.

This family seeks to sleep away from their home as frequently as possible.

- **Case Report 3[5]: Denmark—Abandoned Home and Collapsed Business**

Figure 7 shows a home in Denmark where the owners owned and operated a mink farm since 1990 (*ongoing legal proceedings*).

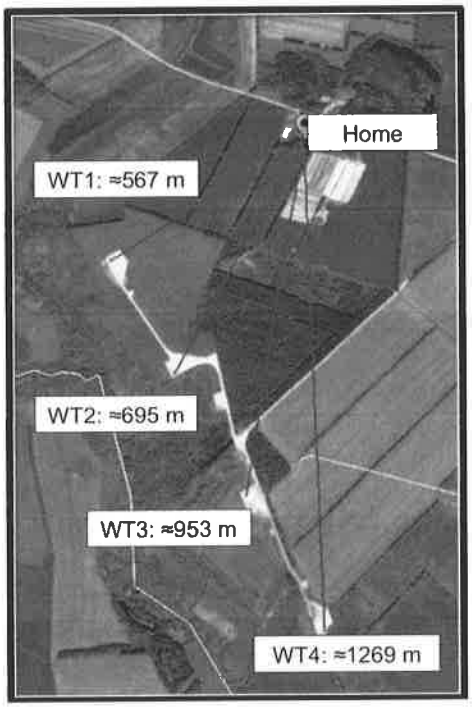


Figure 7. Google Earth image showing 4 wind turbine towers located between ≈0.3 and 0.7 miles (567 - 1269 m) from a residential and mink farm complex —Denmark. (North points upward.)

These 4 turbine towers began operating in 2013. The home was abandoned in 2015. Even though the family no longer inhabited the home, the mink farm continued operations, requiring the property- and farm-owner to remain on the location for extended periods of time.

In 2018, the 57-year-old property owner was formally diagnosed with post-traumatic stress disorder. The mink farm formally closed down in January 2019, after massive amounts of (documented) animal death.

The residence of Ms. Carrie March is slated to have 16 towers within ≈0.3 and 1.8 miles.

[5] Alves-Pereira M, Bakker HHC (2017) Occupational and Residential Exposures to Infrasound and Low Frequency Noise in Aerospace Professionals: Flawed Assumptions, Inappropriate Quantification of Acoustic Environments, and the Inability to Determine Dose-Response. Scientific J Aerosp Eng Mech 1(2):83-98. — Appendix 5.

6. If it is really the case that wind turbines produce a toxic acoustic pollutant, then why are wind power stations being built all over the world?

Apparently, mostly due to ignorance, but perceived economic benefits are also playing an important role.

7. What is the safe distance between wind power stations and residential areas?

Science does not know.

Wind turbine acoustics signatures have been documented in a home 12 km (≈7.4 miles) away from the nearest tower (unpublished data gather by our field-studies).

Other teams in Finland (The Aunio Group[6]) and Australia (Flinders University[7]) have also documented infrasound levels in homes 'far away' from the wind power station responsible for the emissions.

8. *You will be told that:*
Infrasound cannot be heard by humans
and therefore poses no threat to human health.

This position perpetuates a scientifically indefensible position: *what you can't hear won't hurt you*.

This is an ancient assumption, stemming from early 20th century work on the telephone. Given the necessity of focusing on human speech intelligibility and hearing in order to perfect telephone communications, all parts of 'sound' that were inaudible to humans were deemed irrelevant.
Please see the publication offered in Appendix 3 for more historical details.

There are countries that *do have* specific legislation enacted in order to protect their populations against infrasound.

Figure 8 gives an example of permissible exposure levels for *both* occupational and residential situations, specifically for 2, 4, 8 and 16 Hz—all within the infrasound range.

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[6] https://www.auniogroup.com
[7] https://news.flinders.edu.au/blog/2019/06/19/wind-farm-noise-recorded-almost-9km-away/

No.	Premise	Sound pressure levels, dB, in octaval bands of averaged geometric frequencies, Hz				General sound pressure level dB "Lin"
		2	4	8	16	
1.	Different jobs inside industrial premises and production areas:					
	- Different physical intensity jobs	100	95	90	85	100
	- Different intellectual emotional tension jobs	95	90	85	80	95
2.	Populated area	90	85	80	75	90
3.	Living and public premises	75	70	65	60	75

Figure 8. Legislated permissible exposure levels for infrasound in different situations.[8]

9. *You will be told that:*
Wind power stations exist in many countries and no one is complaining.

That would be an untruth.

10. *You will be told that:*
Because of 'global warming,' wind power stations are of crucial importance.

That would be another untruth, even recently verified by researchers from Harvard University:

> *In two papers — published today in the journals Environmental Research Letters and Joule — Harvard University researchers find that the transition to wind or solar power in the U.S. would require five to 20 times more land than previously thought, and, if such large-scale wind farms were built, would warm average surface temperatures over the continental U.S. by 0.24 degrees Celsius.*[9]

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[8] In: Stepanov, V. Biological Effects of Low Frequency Acoustic Oscillations and their Hygienic Regulation. State Research Center of the Russian Federation: Moscow (2000). https://apps.dtic.mil/dtic/tr/fulltext/u2/a423963.pdf

[9] Burrows, L (2018) The down side to wind power. The Harvard Gazette, 4 October. https://news.harvard.edu/gazette/story/2018/10/large-scale-wind-power-has-its-down-side/

11.
Residential ILFN Contamination

Figures 2 and 3 refer specifically to the residence of Ms. Carrie March.
Figure 1, however, suggests that many more residential dwellings may impacted by the High Prairie Wind Power Station.

Figures 9 and 10 provide a view of several, other residences located near the home of Ms. Carrie March, and some of the wind towers in *their* vicinity.

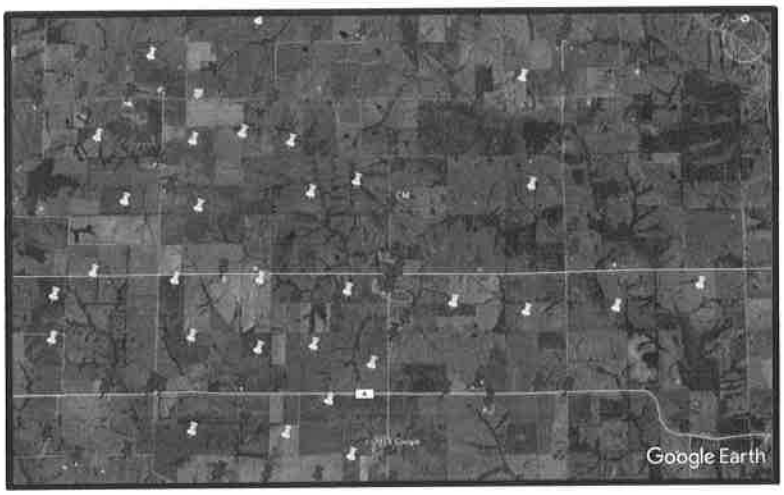

Figure 9. Google Earth image showing other homes (red) near the Carrie March residence (CM) and that are also in close proximity to turbine towers (yellow).

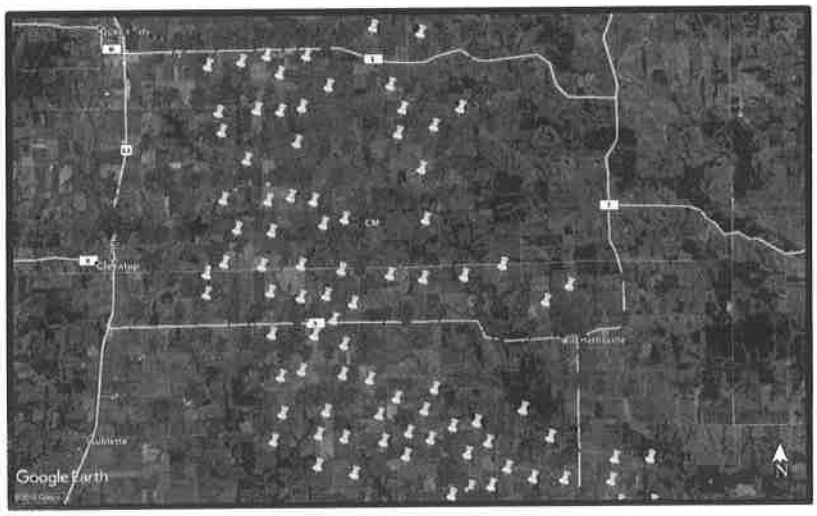

Figure 10. Google Earth image showing other homes (red) near the Carrie March residence (CM) and that are also in close proximity to turbine towers (yellow).

A perusal of Figures 9 and 10 shows that many other family dwellings have a very high probability of having ILFN contamination in their homes.

In my opinion, it is highly likely that in each and every one of these homes, citizens' health will become severely impacted.

12.
Precautionary Principle

The very debilitating adverse health effects caused by ILFN exposure have been scientifically documented in occupational settings since the 1960's.
Science already knows what happens to the (proverbial) canary in the mine.

Wind power stations are the latest type of industrial complexes that are bringing toxic ILFN into the homes, often continuously over a 24-hour period.

To my knowledge, there is no formal 'noise' guideline or ordinance in the State of Missouri that can provide any basis for curtailing the emissions of this agent of disease.

Just as with asbestos, second-hand smoking, and leaded fuels or, more recently, plastics and glyphosate products, the health effects were made evident *before* legislative bodies enacted clauses for the specific purpose of protecting the health of human populations.

Curriculum Vitae

Personal information

First name / Surname **Mariana Alves-Pereira**

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Estoril 2765-294 Portugal

Telephone Mobile: +351-961753209

E-mail m.alvespereira@gmail.com

Skype marianna-alves-pereira

Nationality USA/ EU

Academic Background

Date 2010

Title of qualification awarded **Doctoral degree in Environmental Sciences**

Name and type of organisation providing education Universidade Nova de Lisboa, Caparica, Portugal

Date 2000

Title of qualification awarded **Masters degree in Biomedical Engineering**

Name and type of organisation providing education Drexel University Philadelphia, PA, USA

Date 1995

Title of qualification awarded **Bachelors degree in Physics**

Name and type of organisation providing education State University of New York Stony Brook, NY, USA

Dates 1990

Title of qualification awarded **12th year High School Diploma**

Name and type of organisation providing education Algés Secondary School Lisbon, Portugal

Dates 1988

Title of qualification awarded **10th-11th years High School – Area of Technological Sciences**

Name and type of organisation providing education Fontes Pereira de Melo Secondary School Porto, Portugal

Scientific Awards

2006 - Prevent More Live Better Scientific Research Award
Diagnosis of Vibroacoustic Disease for Legal & Forensic Purposes.
Attributed by the Instituto de Segurança Higiene e Saúde no Trabalho (Portuguese Governmental Institute for Safety, Hygiene & Health in the Workplace).

2005 - Thomé Villar/Boehringer Ingelheim Research Award
Participation of the Central Airways in Vibroacoustic Disease.
Attributed by the Portuguese Lung Society (Sociedade Portuguesa de Pneumologia).

1999 - Young Investigator Award Finalist
Pericardial Thickening in Commercial Airline Flight Crew.
Attributed by the Space Medicine Branch of the Aerospace Medical Association (USA).

Expertise

Acoustics	Infrasound and low frequency noise (ILFN) exposure. Conducted extensive acoustical measurements and analyses in 1/3- and 1/36-octave band, dB Linear, within industrial, urban and residential areas.
Clinical Medicine	Design, implementation and data analyses of clinical studies pertaining to ILFN-exposed populations, including gathering of patient medical and noise exposure histories.
Cellular Biology	Interpretation of light and electron microscopy imaging comparing ILFN-exposed vs. non-exposed cell and tissues of both human and animal models. Analyses of the biological responses to ILFN exposure based on principles of materials and structural engineering and on cytoskeleton dynamics.
Bioengineering	Analysis and interpretation of the response of actin- and tubulin-based structures to ILFN exposures. First to associate cellular and tissue tensegrity architecture to better understand the biological response observed in ILFN-exposed specimens.
International Expert Witness & Consultant	-- Vibroacoustic Disease -- Effects of ILFN on occupationally- or environmentally-exposed human populations.

Teaching Experience

Associate Professor since 2010
Adjunct Professor since 2005.
Assistant Professor since 2002

Dates	Since 2009
Main activities and responsibilities	Coordinating/ Teaching: Physics (Occupational Safety & Health Program) Epidemiology (Occupational Safety & Health Program) Workplace Safety & Health (Safety & Security Program)
Name and address of employer	School of Economic Sciences & Organizations Universidade Lusófona Campo Grande 376, 1749-024 Lisbon, Portugal
Type of business or sector	Higher education

Dates	2007-2013
Main activities and responsibilities	Teaching: Biophysics Lab (Pharmaceutical Sciences Program)
Name and address of employer	School of Health Sciences and Technologies Universidade Lusófona Campo Grande 376, 1749-024 Lisbon, Portugal
Type of business or sector	Higher education

Dates	2005-2007
Main activities and responsibilities	Teaching: Physics (Nursing Program), Coordinating/ Teaching: Biomaterials (Pre-Bologna Radiology Program) Non-ionizing Radiation (Pre-Bologna Radiology Program) Experimental Statistics (Pre-Bologna Radiology Program)
Name and address of employer	Ribeiro Sanches School of Health Sciences Universidade Lusófona Rua dos Telhais aos Olivais, 8-8ª, 1900-693 Lisbon, Portugal
Type of business or sector	Higher education

Dates	2002-2005
Main activities and responsibilities	Coordinating/ Teaching: Acoustical Pollution (Environmental Engineering Program)
Name and address of employer	Department of Environmental Sciences & Engineering Universidade Nova de Lisboa Quinta da Torre, 2829-516 Caparica, Portugal
Type of business or sector	Higher education

Work Experience

Dates	1988-2013
Occupation or position held	**Senior researcher, Assistant Coordinator for the Vibroacoustic Disease Project**
Main activities and responsibilities	Measure low frequency noise; Patient interviews; Interpreting electron microscopy imaging; Data analyses; Preparation of scientific papers for publication; Oral presentations at international scientific meetings and conferences; Organization of scientific conferences; Expert court witness.
Name and address of employer	Centro da Performance Humana, Estrada Nacional 10, Edificio Cinema, 1º Piso, 2615 Alverca, Portugal
Type of business or sector	Biomedical research in occupational medicine (non-for-profit enterprise)

Dates	2010-2012
Occupation or position held	**Administrator**
Main activities and responsibilities	Liaison between NASA officials and European Governmental officials and private enterprises; Procure projects, actions and activities related to sustainable energy and environmental issues of mutual interest to NASA; Preparation of status reports; Oral presentations of ongoing projects at NASA/C3P Annual Technical Workshops.
Name and address of employer	Center for Pollution Prevention (C3P)
Type of business or sector	Ministry of Environment (non-for-profit enterprise)

Dates	2002-2005
Occupation or position held	**Fellowship recipient**
Main activities and responsibilities	Write, enact and develop research project funded by Portuguese Government (POCTI/FCT): "Low frequency noise in public transportation systems in the Greater Lisbon area"
Name and address of employer	IMAR – Instituto do Mar, Pólo da Faculdade de Ciênicias e Tecnologia, Universidade Nova de Lisboa, Quinta da Torre, 2829-516 Caparica, Portugal
Type of business or sector	Higher education / Research

Dates	Feb-Jul 2000
Occupation or position held	**Associate researcher**
Main activities and responsibilities	PCR studies investigating the genetic expression of ubiquitin and ciclogenase-2 in cells exposed to cadmium.
Name and address of employer	Department of Biological Sciences, Hunter College, City University of New York
Type of business or sector	Higher education / Research

Dates	1991-1995
Occupation or position held	**Librarian**
Main activities and responsibilities	Catalogue new books and scientific journals; Manage book lending; Assist with inquiries.
Name and address of employer	Math/Physics Library State University of New York, Stony Brook, NY, USA
Type of business or sector	Academic

Dates	1988-1990
Occupation or position held	**Technical translator**
Main activities and responsibilities	Quality control inspection manuals for the Lockheed C-130 Hercules, P-3P Orion, and Aerospatiale SA-330 Puma aircraft; Avionics, fuel systems and ground support equipment manuals; Scientific research papers developed by the Medical Division Research Team.
Name and address of employer	OGMA-Indústria Aeronautica de Portugal Parque Aeronautico de Alverca, 2615-173 Alverca, Portugal
Type of business or sector	Aeronautical industry

Dates	1982-1985
Occupation or position held	**Summer-hire** (Commercial Section, US Air Force Section, US Information Services)
Main activities and responsibilities	Administrative tasks; Written and simultaneous translations; Public relations. In 1985, collaborated in the organization of President Ronald Reagan's official visit to Lisbon.
Name and address of employer	United States Embassy Av. das Forças Armadas, 1600-081 Lisbon, Portugal

Training Programs

Dates	2001
Title of qualification awarded	**Epidemiological Surveillance Technician**
Name and type of organisation providing education	Institute of Preventive Medicine, School of Medicine, University of Lisbon
Dates	1990
Title of qualification awarded	**C-130 Hercules: Specialization in Engine, Propellers and Auxiliary Power Unit.**
Name and type of organisation providing education	Lockheed Martin Official Training Center OGMA-Indústria Aeronautica de Portugal Parque Aeronautico de Alverca, 2615-173 Alverca, Portugal
Dates	1987
Title of qualification awarded	**Computer programmer** (DOS, DBase III, Cobol, WordStar)
Name and type of organisation providing education	Instituto de Tecnologia Avançada para a Educação Porto, Portugal

Languages

Native speaker: **English/Portuguese**

Other languages: **French, Spanish**

Relevant publications

Alves-Pereira M, Bakker HHC (2017) *Occupational and residential exposures to infrasound and low frequency noise in aerospace professionals: Flawed assumptions, inappropriate quantification of acoustic environments, and the inability to determine dose-response*. Scientific Journal on Aerospace Engineering and Mechanics, 1(2):83-98.

Alves-Pereira M, Castelo Branco NAA (2007) *Vibroacoustic disease: Biological effects of infrasound and low frequency noise explained by mechanotransduction cellular signaling.* Progress Biophysics & Molecular Biology, 93: 256-279.

Alves-Pereira M, Joanaz de Melo J, Castelo Branco, NAA (2005) *Pericardial biomechanical adaptation to low frequency noise stress.* In: A. Méndez-Vilas (ed.) Recent Advances in Multidisciplinary Applied Physics. Elsevier: London, 2005: 363-7. (ISBN: 978-0-08-044648-6)

Alves-Pereira M (1999) *Noise-induced extra aural pathology. A review and commentary.* Aviation, Space and Environmental Medicine, 70 (3, Suppl.): A7-A21.

(Annex I: Complete List of Publications)

LISTING OF SCIENTIFIC PUBLICATIONS

Mariana Alves-Pereira, Ph.D.

2019

Alves-Pereira M, Rapley B, Bakker HHC, Summers R. (2019) **Acoustics and Biological Structures** IN: Acoustics of Materials. Abiddine ZE, Ogam E (editors). IntechOpen, London. DOI: 10.5772/intechopen.82761.
https://www.intechopen.com/online-first/acoustics-and-biological-structures

Alves-Pereira M, Bakker HHC, Rapley B, Summers R. (2019) **Residential acoustical environments with predominant lower-frequency components: Why measuring inside the home is important. – Submitted for publication**

Alves-Pereira M, Krough C, Bakker HHC, Summers R, Rapley B (2019) **Infrasound and low frequency noise guidelines – Antiquated and irrelevant for protecting populations. – Submitted for publication**. Proceedings of the 26th International Congress on Sound & Vibration, Montreal, Canada, July 7-11, 2019. (Peer-Reviewed Conference Paper, No. 682)

2018

Alves-Pereira M, Bakker HHC, Rapley B, Summers R. (2018). **Infrasound and Low Frequency Noise – Shall we measure it properly?** Engineers Ireland Journal. (Jan 23)
http://www.engineersjournal.ie/2018/01/23/ilfn-infrasound-low-frequency-noise-turbine-health/

2017

Alves-Pereira M, Bakker HHC (2017) **Occupational and Residential Exposures to Infrasound and Low Frequency Noise in Aerospace Professionals: Flawed Assumptions, Inappropriate Quantification of Acoustic Environments, and the Inability to Determine Dose-Response.** Scientific J Aerosp Eng Mech 1(2):83-98.

Bakker HHC, Alves-Pereira M, Summers SR (2017) **Citizen Science Initiative: Acoustical Characterisation of Human Environments.** Proceedings International Conference Biological Effects of Noise (ICBEN 2017). Zurich, Switzerland, No. 3653, 12 pages.

Bakker, H. H. C., Rapley, B. I., Summers, S. R., Alves-Pereira, M., Dickinson, P. J. (2017). **An Affordable Recording Instrument for the Acoustical Characterisation of Human Environments**. Paper presented at the ICBEN 2017, Zurich, Switzerland (Paper No. 3654).

Rapley, B., Alves-Pereira, M., Bakker H (2017) **The inadequacy of the A-frequency weighting for the assessment of adverse effects on human populations**. Paper presented at ICBEN 2017, Zurich, Switzerland (Paper No. 3873).

Rapley, B. I., Bakker, H. H. C., Alves-Pereira, M., Summers, S. R. (2017). **Case Report: Cross-sensitisation to infrasound and low frequency noise.** Paper presented at the ICBEN 2017, Zurich, Switzerland (Paper No. 3872).

2015

Castelo Branco NAA, Alves-Pereira M, Martinho Pimenta A, Reis Ferreira J (2015) **Clinical protocol for evaluating pathology induced by low frequency noise exposure**. Euronoise 2015, Maastricht, The Netherlands, 31 May-3 Jun, 6 pages.

Castelo Branco NAA, Alves-Pereira M, Martinho Pimenta A, Reis Ferreira J (2015) **Low frequency noise-induced pathology: contributions provided by the Portuguese wind turbine case**. Euronoise 2015, Maastricht, The Netherlands, 31 May-3 Jun, 5 pages.

2014

Alves-Pereira M, Castelo Branco NAA. **Letter to the Editor re: "How the factoid of wind turbines causing vibroacoustic disease came to be 'irrefutably' demonstrated"**. Australian & New Zealand Journal Public Health 2014; 38(2): 191-192.

Mendes AP, Bonança I, Jorge A, Alves-Pereira M, Castelo Branco NAA, Caetano M, Oliveira N, Graça A, Santos C, Ferraria R. **Voice acoustic profile of males exposed to occupational infrasound and low-frequency noise.** Laryngology & Voice 2014; 4(1): 12-20.

2012

Mendes AP, Graça A, Jorge A, Alves-Pereira M, Castelo Branco NAA, Freitas A, Laranjeira M, Bonança I. **The effects of ILFN-exposure on voice acoustic parameters of commercial cabin crewmembers.** Laryngology & Voice 2012; 2(2): 70-80.

Alves-Pereira M. **Review of the wind turbine health study: Report of independent expert panel**, as prepared for the Massachusetts Department of Environmental Protection & Massachusetts Department of Public Health. March 2012.
http://docs.wind-watch.org/MassDEP-wind-health-2-Alves_Pereira.pdf

2010

Alves-Pereira M. **Infrasound and low frequency noise: Quantification in several rural and urban environments.** Revista Lusófona de Ciências e Tecnologias da Saúde 2010 7(1): 91-108. (Bilingual)
http://revistas.ulusofona.pt/index.php/revistasaude/article/view/1237/1003

Castelo Branco NAA, Costa e Curto T, Mendes Jorge L, Cavaco Faísca J, Amaral Dias L, Oliveira P, Martins dos Santos J, Alves-Pereira M. **Family with wind turbines in close proximity to home: follow-up of the case presented in 2007.** Proceedings of the 14th International Meeting on Low Frequency Noise, Vibration and Its Control. Aalborg, Denmark, 9-11 June, 2010, 31-40.

2009

Alves-Pereira M, Castelo Branco NAA. **Infrasound and low frequency noise dose responses: contributions**. Revista Lusófona de Ciências e Tecnologias da Saúde 2009 6(1): 31-44. (Bilingual)
http://revistas.ulusofona.pt/index.php/revistasaude/article/view/725/605

Alves-Pereira M., Castelo Branco NAA. **Understanding the Biological Responses Elicited by Low Frequency Noise Exposure: Contributions to Vibroacoustic Disease Research** (No. 079R-Oral presentation). Second International Fascia Research Congress, Amsterdam, The Netherlands, 27-30 October, 2009.

Castelo Brnaco NAA, Alves-Pereira M. **Production of Functional Collagen Units in the Absence of Inflammatory Processes as a Response to Low Frequency Noise Exposure** (No. J_075-Oral presentation). Second International Fascia Research Congress, Amsterdam, The Netherlands, 27-30 October, 2009.

Alves-Pereira M, Castelo Branco NAA. **Low Frequency Noise Exposure Destroys Tubulin- and Actin-based Structures** (No. 077-Poster presentation). Second International Fascia Research Congress, Amsterdam, The Netherlands, 27-30 October, 2009.

Oliveira P, Martins dos Santos J, Mendes JJ, Alves-Pereira M, Castelo Branco NAA. **Perivasculo-Ductal Connective Tissue in the Parotid Gland of Wistar Rats Exposed to Low Frequency Noise** (J_092-Poster presentation). Second International Fascia Research Congress, Amsterdam, The Netherlands, 27-30 October, 2009.

2008

Mendes AP, Graça A, Santos CP, Galvão A, Carvalho RO, Sousa MJ, Alves-Pereira M, Castelo Branco NAA. **Voice acoustic analyses in airline cabin crewmembers.** Proceedings Internoise2008. Shangai, China, 2008; No. IN-08-595, 13 pages.

Mendes AP, Graça A, Santos CP, Galvão A, Carvalho RO, Sousa MJ, Alves-Pereira M, Castelo Branco NAA. **Voice acoustic analyses in commercial airline pilots**. Proceedings Internoise2008. Shangai, China, 2008; No. IN-08-591 , 11 pages.

2007

Alves-Pereira M, Castelo Branco NAA. **Vibroacoustic disease: Biological effects of infrasound and low frequency noise explained by mechanotransduction cellular signaling.** Progress Biophysics & Molecular Biology 2007; 93: 256-279.

Alves-Pereira M, Castelo Branco NAA. **On the impact of infrasound and low frequency noise on public health: 2 cases of residential exposure.** Revista Lusófona de Ciências e Tecnologias da Saúde 2007; 4(2): 186-200. (Bilingual)
http://revistas.ulusofona.pt/index.php/revistasaude/article/view/670/564

Castelo Branco NAA, Reis Ferreira J, Alves-Pereira M. (2007). **Respiratory pathology in vibroacoustic disease: 25 years of research.** Revista Portuguesa Pneumologia 2007; XIII (1): 129-135.

Alves-Pereira M, Castelo Branco, NAA. **The scientific arguments against vibroacoustic disease.** Proceedings Internoise2007. Istanbul, Turkey, 2007; No. IN-07-505, 7 pages. (ISBN: 80-01-03055-5)

Alves-Pereira M, Castelo Branco, NAA. **Public health and noise exposure: the importance of low frequency noise.** Proceedings Internoise2007. Istanbul, Turkey, 2007; No. IN-07-137, 10 pages. (ISBN: 80-01-03055-5)

Alves-Pereira M, Castelo Branco, NAA. **Infrasound and low frequency noise dose responses: contributions.** Proceedings Internoise2007. Istanbul, Turkey, 2007; No. IN-07-443, 10 pages. (ISBN: 80-01-03055-5)

Alves-Pereira M, Castelo Branco, N.A.A. **In-home wind turbine noise is conducive to vibroacoustic disease.** *Proceedings of the Second International Meeting on Wind Turbine Noise*, Lyon, France, Sep 20-21, Paper No. 3, 11 pages.

Castelo Branco, NAA, Monteiro M, Reis Ferreira R, Mendes CP, Alves-Pereira M. **Diagnosing vibroacoustic disease for legal purposes.** Proceedings Internoise2007. Istanbul, Turkey, 2007; No. IN-07-506, 8 pages. (ISBN: 80-01-03055-5)

Castelo Branco, NAA, Monteiro M, Reis Ferreira R, Monteiro E, Alves-Pereira M. **Bronchoscopy in vibroacoustic disease I – Pink Lesions.** Proceedings Internoise2007. Istanbul, Turkey, 2007; No. IN-07-507, 7 pages. (ISBN: 80-01-03055-5)

2006

Castelo Branco NAA, Alves-Pereira M. **A doença vibroacústica**. Revista Segurança 2006; XLI (171-Supl Março/Abril):1-20.

Mendes A, Alves-Pereira M, Castelo Branco NAA. **Voice acoustic patterns of patients diagnosed with vibroacoustic disease**. Revista Portuguesa Pneumologia 2006; XII (4): 375-382.

Reis Ferreira J, Mendes CP, Alves-Pereira M, Castelo Branco NAA. **Respiratory squamous cell carcinomas in vibroacoustic disease.** Revista Portuguesa Pneumologia 2006; XII (5): 539-544.

Reis Ferreira J, Albuquerque e Sousa J, Foreid P, Antunes M, Cardoso S, Alves-Pereira M, Castelo Branco NAA. **Abnormal respiratory drive in vibroacoustic disease**. Revista Portuguesa Pneumologia 2006; XII (4): 369-374.

Reis Ferreira J, Monteiro MB, Tavares F, Serrano I, Monteiro E, Mendes CP, Alves-Pereira M, Castelo Branco NAA. **Involvement of central airways in vibroacoustic disease – Thomé Villar/Boehringer Ingelheim Award 2004**. Revista Portuguesa Pneumologia 2006; XII (2): 93-105.

Da Fonseca J, Martins dos Santos J, Castelo Branco NAA, Alves-Pereira M, Grande N, Oliveira P, Martins AP. **Noise-induced gastric lesions: A light and scanning electron microscopy study of the alterations of the rat gastric mucosa induced by low frequency noise.** Central European Journal of Public Health 2006; 14 (1): 35-38.

Alves-Pereira M, Castelo Branco NAA. **Biotensigridade – O novo modelo da célula e a doença vibroacústica. [Biotensegrity – the new cell model and vibroacoustic disease]**. XXII Congresso de Pneumologia/IV Congresso Luso-Brasileiro de Pneumologia, Centro de Congressos do Estoril, 8-10 Dezembro 2006. Revista Portuguesa de Pneumologia; XII (6-Suplemento): S110. (Abstract) (Portuguese)

Monteiro E, Alves-Pereira M, Castelo Branco NAA. **As células em escova e a doença vibroacústica. [Brush cells and vibroacoustic disease]**. XXII Congresso de Pneumologia/IV Congresso Luso-Brasileiro de Pneumologia, Centro de Congressos do Estoril, 8-10 Dezembro 2006. Revista Portuguesa de Pneumologia; XII (6-Suplemento): S111. (Abstract) (Portuguese)

Castelo Branco NAA, Monteiro M, Reis Ferreira J, Alves-Pereira M. **O aparelho respiratório na doença vibroacústica. [The respiratory tract in vibroacoustic disase]**. XXII Congresso de Pneumologia/IV Congresso Luso-Brasileiro de Pneumologia, Centro de Congressos do Estoril, 8-10 Dezembro 2006. Revista Portuguesa de Pneumologia; XII (6-Suplemento): S109. (Abstract) (Portuguese)

Castelo Branco NAA, Monteiro M, Tavares F, Monteiro E, Reis Ferreira J, Alves-Pereira M. **Aspectos morfológicos da basal sub-epitelial respiratória em doentes com a doença vibroacústica. [Morphological aspects of the basal subepithelium in vibroacoustic disease patients]**. XXII Congresso de Pneumologia/IV Congresso Luso-Brasileiro de Pneumologia, Centro de Congressos do Estoril, 8-10 Dezembro 2006. Revista Portuguesa de Pneumologia; XII (6-Suplemento): S112. (Abstract) (Portuguese)

2005

Alves-Pereira M, Joanaz de Melo J, Castelo Branco, NAA. **Pericardial biomechanical adaptation to low frequency noise stress**. IN: A. Méndez-Vilas (ed.) Recent Advances in Multidisciplicnary Applied Physics. Elsevier: London, 2005: 363-7. (ISBN: 978-0-08-044648-6)

Alves-Pereira M, Joanaz de Melo J, Castelo Branco, NAA. **Actin- and tubulin-based structures under low frequency noise stress**. IN: A. Méndez-Vilas (ed.) Recent Advances in Multidisciplinary Applied Physics. Elsevier: London, 2005: 955-79 (ISBN: 978-0-08-044648-6)

Alves-Pereira M, Joanaz de Melo J, Castelo Branco, NAA. **Low frequency noise exposure and biological tissue: reinforcement of structural integrity?** IN: A. Méndez-Vilas (ed.) Recent Advances in Multidisciplinary Applied Physics. Elsevier: London, 2005: 961-6 (ISBN: 978-0-08-044648-6)

Da Fonseca J, Martins dos Santos J, Castelo Branco NAA, Alves-Pereira M, Grande NR, Oliveira P. **Noise-induced duodenal lesions.** European Journal of Anatomy 2005; 9(1): 29-33.

Alves-Pereira M, Marques MC, Castelo Branco NAA. **Biological mechanisms and targets of low frequency noise exposure.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 526 (9 pages).

Alves-Pereira M, Fragata JI, Monteiro E, Sousa Silva D, Castelo Branco NAA. **The pericardium in vibroacoustic disease III – A new structure.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 569 (8 pages).

Alves-Pereira M, Motylewski J, Kotlicka E, Castelo Branco NAA. **Low frequency noise legislation.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 582 (8 pages).

Alves-Pereira M. **Low frequency noise exposure as a confounding factor in biomedical science.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 583 (8 pages).

Alves-Pereira M. **...And again low frequency noise – A possible solution.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 584 (8 pages).

Castelo Branco NAA, Marques MC, Alves-Pereira M. **Physiopathology of vibroacoustic disease.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 563 (6 pages).

Cunha Ribeiro L, Crespo FF, Freire I, Afonso H, Castelo Branco MSN, Marques MC, Alves-Pereira M, Castelo Branco NAA. **Hemostasis and coagulation changes in vibroacoustic disease.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 564 (8 pages).

Castelo Branco NAA, Reis Ferreira J, Marques MC, Alves-Pereira M. **Auto-immune disorders in vibroacoustic disease.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 565 (6 pages).

Araujo A, Carranca J, Alves-Pereira M, Castelo Branco NAA. **Echocardiography in vibroacoustic disease.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 567 (9 pages).

Castelo Branco NAA, Fragata JI, Martins AP, Monteiro E, Alves-Pereira M. **The pericardium in vibroacoustic disease I – morphological features.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 568 (9 pages).

Castelo Branco NAA, Fragata JI, Marques MC, Monteiro E, Alves-Pereira M. **The pericardium in vibroacoustic disease II – cellular death pathways.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 570 (8 pages).

Reis Ferreira J, Mendes CP, Alves-Pereira M, Castelo Branco NAA. **Respiratory pathology in vibroacoustic disease - Current findings.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 571 (7 pages).

Monteiro MB, Reis Ferreira J, Mendes CP, Serrano I, Tavares F, Alves-Pereira M, Castelo Branco NAA. **Respiratory pathology in vibroacoustic disease – Specific morphological changes.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 572 (9 pages).

Foreid P, Martinho Pimenta AJF, Alves-Pereira M, Castelo Branco NAA. **Neuropsychological issues in vibroacoustic disease - Current findings.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 573 (10 pages).

Foreid P, Martinho Pimenta AJF, Alves-Pereira M, Castelo Branco NAA. **Neurological issues in vibroacoustic disease – Epilepsy.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 574 (9 pages).

Reis Ferreira J, Albuquerque e Sousa J, Foreid P, Antunes M, Alves-Pereira M, Castelo Branco NAA. **Neurological issues in vibroacoustic disease - Respiratory control.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 575 (6 pages).

Foreid P, Martinho Pimenta AJF, Alves-Pereira M, Castelo Branco NAA. **Behavioural and psychological changes in vibroacoustic disease.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 576 (9 pages).

Da Fonseca J, Mirones J, Martins dos Santos J, Oliveira O, Alves-Pereira M, Castelo Branco NAA. **Gastrointestinal problems in vibroacoustic disease.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 577 (8 pages).

Martins dos Santos J, Albuquerque e Sousa J, Marques MC, Monteiro E, Alves-Pereira M, Castelo Branco NAA. **Urinary system – Current findings and ongoing studies.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 578 (8 pages).

Casetlo Branco NAA, Alves-Pereira M. **Personal experiences of vibroacoustic disease patients with occupational or environmental exposures.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 579 (7 pages).

Castelo Branco NAA, Alves-Pereira M, Araújo A, Reis Ferreira J, Joanaz de Melo. **Environmental vibroacoustic disease – An example of environmental low frequency noise exposure.** Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 580 (8 pages).

Castelo Branco NAA, Rodriguez E, Alves-Pereira M. **Forensic features in vibroacoustic disease studies**. Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005: No. 581 (9 pages).

2004

Castelo Branco NAA, Alves-Pereira M. **Vibroacoustic disease**. Noise & Health 2004; 6(23): 3-20.

Castelo Branco NAA, Monteiro E, Costa e Silva A, Martins dos Santos J, Reis Ferreira J, Alves-Pereira M. **The lung parenchyma in low frequency noise exposed Wistar rats.** Revista Portuguesa Pneumologia 2004; X (1): 77-85.

Martins dos Santos J, Grande NR, Castelo Branco NAA, Zagalo C, Oliveira P, Alves-Pereira M. **Lymphatic lesions in vibroacoustic disease**. European Journal Lymphology 2004; 12(40): 17-20.

Alves-Pereira M, Joanaz de Melo J, Marques MC, Castelo Branco NAA. **Vibroacoustic disease – the response of biological tissue to low frequency noise**. Proceedings 11th International

Meeting on Low Frequency Noise and Vibration and its Control. Maastricht, Holland, 2004; 295-308.

Alves-Pereira M, Joanaz de Melo J, Motylewski J, Kotlicka E, Castelo Branco NAA. **Biomedical research, legislation and the low frequency noise contaminant.** Proceedings 11th International Congress on Sound & Vibration. St. Petersburg, Russia, 2004; 1729-1736.

Alves-Pereira M, Joanaz de Melo J, Castelo Branco NAA. **Public transportation and low frequency noise: a health hazard?** Proceedings 11th International Congress on Sound & Vibration. St. Petersburg, Russia, 2004; 1761-1766.

Alves-Pereira M, Joanaz de Melo J, Castelo Branco NAA. **Low frequency noise in subways.** Proceedings Internoise2004. Prague, Czech Republic, 2004; No. 641, 5 pages. (ISBN: 80-01-03055-5)

Alves-Pereira M, Joanaz de Melo J, Castelo Branco NAA. **Low frequency noise in trams.** Proceedings Internoise2004. Prague, Czech Republic, 2004; No. 642, 5 pages. (ISBN: 80-01-03055-5)

Alves-Pereira M, Joanaz de Melo J, Castelo Branco NAA. **Low frequency noise in trains.** Proceedings Internoise2004. Prague, Czech Republic, 2004; No. 643, 5 pages. (ISBN: 80-01-03055-5)

Alves-Pereira M, Joanaz de Melo J, Motylewski J, Kotlicka E, Castelo Branco NAA. **Biomedical research and the low frequency noise contaminant.** Proceedings Internoise2004. Prague, Czech Republic, 2004; No. 644, 7 pages. (ISBN: 80-01-03055-5)

Castelo Branco NAA, Alves-Pereira M. **Vibroacoustic disease- what is known to date.** Proceedings 11th International Meeting on Low Frequency Noise and Vibration and its Control. Maastricht, Holland, 2004; 269-284.

Araujo A, Alves-Pereira M, Joanaz de Melo J, Castelo Branco NAA. **Environmentally-induced vibroacoustic disease in a suburban family.** Proceedings 11th International Congress on Sound & Vibration. St. Petersburg, Russia, 2004; 1767-1774.

Castelo Branco NAA, Alves-Pereira M. **Vibroacoustic disease- current concepts.** Proceedings 11th International Congress on Sound & Vibration. St. Petersburg, Russia, 2004; 1775-1782.

Castelo Branco NAA, Alves-Pereira M. **Vibroacoustic disease - update of current knowledge.** Proceedings Internoise2004. Prague, Czech Republic, 2004; No. 613, 8 pages. (ISBN: 80-01-03055-5)

Araujo A, Alves-Pereira M, Joanaz de Melo J, Castelo Branco NAA. **Vibroacoustic disease in a ten-year-old male.** Proceedings Internoise2004. Prague, Czech Republic, 2004; No. 634, 7 pages. (ISBN: 80-01-03055-5)

Foreid P, Martinho Pimenta AJF, Alves-Pereira M, Castelo Branco NAA. **Neurophysiological aspects of vibroacoustic disease.** Proceedings 11th International Congress on Sound & Vibration. St. Petersburg, Russia, 2004; 1737-1744.

Reis Ferreira J, Mendes CP, Antunes M, Alves-Pereira M, Castelo Branco NAA. **Loss of the neurological control of breathing in vibroacoustic disease patients.** Proceedings 11th International Congress on Sound & Vibration. St. Petersburg, Russia, 2004; 1745-1752.

Castelo Branco NAA, Fragata JI, Martins AP, Monteiro E, Alves-Pereira M. **Pericardial cellular death in vibroacoustic disease.** Proceedings 11th International Congress on Sound & Vibration. St. Petersburg, Russia, 2004; 1753-1760.

Mendes CP, Reis Ferreira J, Alves-Pereira M, Castelo Branco NAA. **Vibroacoustic disease and respiratory pathology I - Tumours.** Proceedings Internoise2004. Prague, Czech Republic, 2004; No. 636, 5 pages. (ISBN: 80-01-03055-5)

Reis Ferreira J, Albuquerque e Sousa J, Mendes CP, Antunes M, Alves-Pereira M, Castelo Branco NAA. **Vibroacoustic disease and respiratory pathology II – PCO_2 response.** Proceedings Internoise2004. Prague, Czech Republic, 2004; No. 637, 6 pages. (ISBN: 80-01-03055-5)

Monteiro M, Reis Ferreira J, Mendes CP, Alves-Pereira M, Castelo Branco NAA. **Vibroacoustic disease and respiratory pathology III – Tracheal & bronchial lesions.** Proceedings Internoise2004. Prague, Czech Republic, 2004; No. 638, 5 pages. (ISBN: 80-01-03055-5)

Reis Ferreira J, Albuquerque e Sousa J, Mendes CP, Antunes M, Alves-Pereira M, Castelo Branco NAA. **Vibroacoustic disease and respiratory pathology IV – Lung & pleura in a lung cancer patient.** Proceedings Internoise2004. Prague, Czech Republic, 2004; No. 639, 4 pages. (ISBN: 80-01-03055-5)

Reis Ferreira J, Mendes CP, Monteiro M, Marques MC, Alves-Pereira M, Castelo Branco NAA. **Vibroacoustic disease - associated respiratory pathology.** Proceedings 11th International Meeting on Low Frequency Noise and Vibration and its Control. Maastricht, Holland, 2004; 285-294.

2003

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Castelo Branco NAA, Monteiro E, Costa e Silva A, Reis Ferreira J, Alves-Pereira M. **Respiratory epithelia in Wistar rats.** Revista Portuguesa Pneumologia 2003; IX: 381-88

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Infrasound and Low Frequency Noise – Shall we measure it properly?

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On the *Engineers Ireland* website, a search on "infrasound" or "low frequency noise" yields zero results. A search on "noise" however, yields 39 results. Why is it that infrasound and low frequency noise (ILFN) is still such a taboo subject? While it is improbable that this particular question will be answered here, an exposé of ILFN will be provided with a brief historical account of how and why ILFN was ultimately deemed irrelevant for human health concerns.

Infrasound and Low Frequency Noise (ILFN) are airborne pressure waves that occur at frequencies ≤ 200 Hz. These may, or may not, be felt or heard by human beings. In order to clarify concepts, in this report the following definitions are used: *acoustic phenomena:* airborne pressure waves that may or may not be perceived by humans; *sound:* acoustic phenomena that can be captured and perceived by the human ear; *noise*: sound that is deemed undesirable; *vibration:* implies a solid-to-solid transmission of energy.

Harvey Fletcher, the Telephone and the deciBel

In the early part of the 20th-century, Harvey Fletcher of the Western Electrics Laboratories of AT&T, was tasked with improving the quality of reception in the telephone. To generate the sounds in a telephone earpiece, he used an a.c., voltage and had some of his colleagues rate the loudness of the sound received compared to the quietest tone heard. The company was already using a logarithmic scale to describe the power in an electrical cable and it made sense to rate the loudness of the sounds also on

a logarithmic scale related to the quietest voltage that could just be heard. Initially he called this metric a "sensation unit" but later to commemorate their founder Alexander Graham Bell, they renamed it the "Bel." A tenth of a Bel became known as the deciBel, corrupted to decibel, which has stuck with the scientific community to this day.

Fletcher-Munson Equal Loudness Curves and the dBA metric

To address the problem of industrial noise in the early 20th century, measurement was essential, as was a metric. At that time, researchers were critically aware that the readings on a sound level meter did not represent how loud or intense the sound was with respect to the subject's perception of hearing. From a biomedical perspective, this concept of perception is subjective, and changes between individuals and over timescales from minutes to decades. These serious constraints notwithstanding, it was acknowledged that some average measure of loudness would have some value for medicine and public health.

Harvey continued his research with Wilden Munsen, one of his team, by varying the frequency of the electricity to give pure tones, to which it is understood twenty-three of his colleagues listened to different levels of loudness, again through a simple telephone earpiece. (It is assumed they all had good hearing). They were then asked to score the sounds for equal loudness to that generated by an alternating current at 1000 cycles per second. The level of the sound of course depended on the voltage applied, which could be measured. It is important to note two significant constraints here: The sounds were 'pure' sine waves, which are not common in nature, and the headphones enclosed the ear of the subject. This is a very unnatural way to listen to a very unnatural sound.

The numerical results of this study are known as the Fletcher-Munsen Curves (Fig 1). The (logarithmic) units of these curves are known as "phons," and the inverse of the 40 phon curve forms the basis of the A-frequency weighting scale used everywhere today (Fig 2).

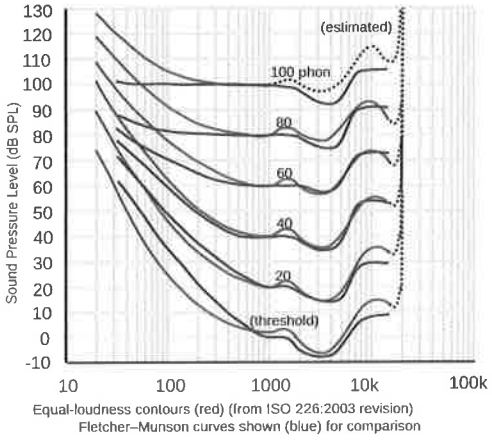

Figure 1. Fletcher Munson Curves [2]

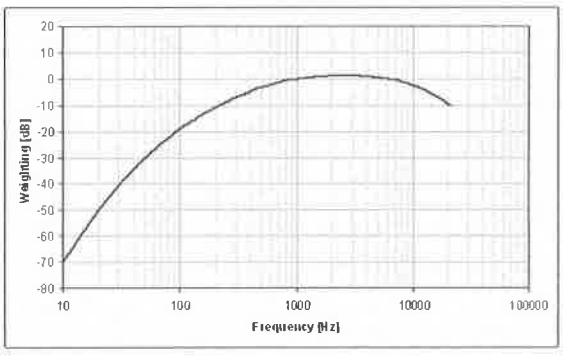

Figure 2. A-weighting frequency response curve [3]

The minimum pressure required for humans to perceive sound at 1000 Hz is considered to be 20 micropascal, or an intensity of 10^{-12} watts per square meter. This corresponds to 0 phon on Figure 1, and 0 dBA in Figure 2. For all its shortcomings, the A-Weighting has endured for decades and has become the *de facto* standard for environmental noise measurement. But is the A-weighting sufficient for all circumstances? The answer is an emphatic "No." It relates to the perception of loudness, which heavily discounts all frequencies below 1000 Hz and ends at 20 Hz. This 20-Hz limit was a consequence of equipment limitations of the 1920s and 30s, but has remained as the lower limit of human hearing to this day. The assumption that harm from excessive noise exposure is directly related to the perception of loudness has also remained to this day. Observe in Fig 2 that, at 10 Hz, there is a 70-dB difference between what is measured and what is, *de facto*, present in the environment. In other words, three-and-a-half orders of magnitude of energy are discounted at this frequency. The implications for public health are considerable, and within this line of reasoning, any event below 20 Hz becomes of no consequence whatsoever, and more so because it is not implicated in the classical effects of excessive noise exposure: hearing loss.

There are also issues of time and frequency resolution. Acoustic phenomena are time varying events. A 10-min average of acoustic events can hide more than it reveals. Similarly, segmenting frequencies into octave or 1/3-octave bands for analysis can also hide much that needs to be seen. Today, affordable and highly portable equipment can record acoustical environments, and allow for post-analysis in sub-second time increments and 1/36-octave resolution. Waveform analysis from the sound file directly can achieve an even better resolution.

Preliminary Results from Field Studies Conducted in Ireland

The following results, recently obtained in field-studies conducted in Ireland (Jul-Nov 2017), show why such resolution is needed to understand ILFN-rich environments. The classical metric (in dBA, 10-min averages and 1/3-octave bands) will be contrasted with what is needed for human health-related concerns (in dB with no frequency weighting, and resolutions of 0.2s and 1/36-octave bands), and not merely compliance with regulations.

Equipment and Methods

Acoustical environments were recorded with a SAM Scribe FS recording system, a 2-channel recorder with sampling rates up to 44.1 kHz at 16-bit resolution and linear response down to almost 0.1 Hz [4-6]. Recordings were saved as uncompressed WAV files including the 1000 Hz/94 dB reference calibration tone prior to and after measurements. Windshields were placed on both microphones during the entire measurement sessions. Microphones were attached to tripods at approximately 1.5 m above the ground.

Location

Five homes located around the same industrial wind turbine (IWT) development have been the object of study. The data presented here refers to Home 1 (Fig 3). Table 1 shows the dates and times of all recordings that have been made to date in this Home. The recordings selected for analysis and presentation herein were chosen on their educational value.

Table 1.
Dates and times of recordings.

Home No.	Date	Time	Blue Channel	Red Channel
1	04 Jul	04:05 – 06:48	In child's bedroom-1	In child's bedroom-2
	05 Jul	15:33 – 17:50		
	10 Oct	17:40 – 18:43		

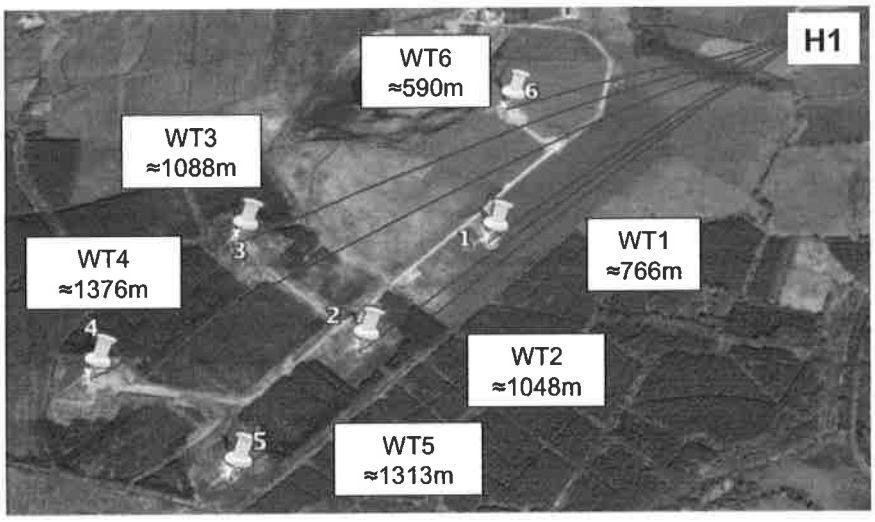

Figure 3. Reconstruction using a Google Earth Image and showing the relative position of Home 1 and each of the six industrial wind turbines.

Results

The information classically obtained with the dBA metric, 1/3-octave bands and 10-min averaging (on October 10th, 2017, at 18:30) is given in Figures 4 and 5. Weather conditions obtained from Met Éireann for the closest weather tower at this time were as follows: Air temperature: 14ºC, Precipitation: 0.1 mm, Mean Sea-Level Pressure: 1006.0 hPa, Wind Speed: 5.1 m/s (10 kt), Wind Direction: Southwest (200º az).

The values obtained for the sound pressure level and 1/3-octave bands are seen in Figures 4 and 5. The overall dBA metric (red bars labelled "Tot") reflects the sound that humans would hear if they were present in this environment. The sound pressure level in dBLin metric (grey bars labelled "Tot"), reflect the amount of acoustic energy to which

humans are concomitantly exposed. The growing discrepancy between the two can be seen as the frequency falls below 1000 Hz.

Figure 6 shows the sonogram corresponding to the same 10-min period. This visual representation of time- and frequency-varying acoustic events provides much more information than the classical approach (Figs 4 and 5). Here short-term events can be seen in the region of 20-50 Hz (Fig 6). Tonal components can be seen at 10 Hz and 20 Hz that are not steady in amplitude and may be amplitude modulated, i.e., where the amplitude of the pressure is not continuous and varies periodically with time. The 10-min averages, used in almost all legislation, hide these variations and are representative only of tonal components that are essentially unvarying over the 10-min period in question.

The periodogram (Fig 7) over the same 10 minutes shows that there are distinct tonal components that form a harmonic series. When IWTs are the source of ILFN, the rotating blades generate repeated pressure waves as each blade replaces the previous one at any position. A harmonic series is formed with the "blade pass frequency" as the fundamental frequency (0.8 Hz here). These harmonics constitute what is called the *wind turbine signature* [7], which is impossible to identify using the classical dBA, 1/3-octave, 10-min averaging methodology.

Final Thoughts

Health concerns associated with excessive exposure to ILFN in the workplace have been around since the industrial boom in the 1960s [8]. In recent years, however, residential neighbourhoods have also begun to be flooded with ILFN [9-14]. The Family living in Home 1, for example, has abandoned their residence due to severe health deterioration in all family members. *Accredited acousticians cannot ascertain compliance levels for ILFN because there are none* - the vast majority of regulations worldwide do not cover this part of the acoustic spectrum. Nevertheless, Public Health Officials and Agencies should fulfil their job descriptions by becoming aware of the limitations of current noise guidelines and regulations. Alternatives exist to gather the acoustic information relevant to the protection of human populations, in both occupational and residential settings. Noise regulations and guidelines need urgent updating in order to appropriately reflect ILFN levels that are dangerous to human health.

Home 1 – A-weighting, 1/3 octave bands (0.5 Hz – 4000 Hz), 10–min average - Red Channel

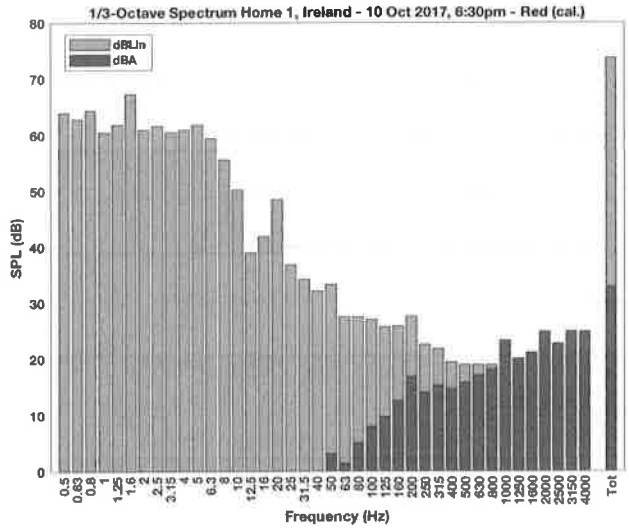

Figure 4. Data covers a 10-min interval analyzed between 0.5–4000 Hz, in 1/3-octave bands, as recorded in Home 1, on 10 Oct 2017, at 18:30 (red microphone, i.e. inside child's bedroom-2).
The red bars are A-weighted values, while the gray bars indicate the acoustic energy that is, *de facto* present, in dBLin. In this environment, the human being would perceive through the ear an overall A-weighted pressure-level of approximately 34 dBA (Tot - red bar), while being concomitantly exposed to an overall acoustic pressure-level of approximately 74 dBLin (Tot – grey bar).

Home 1 – A-weighting, 1/3 octave bands (0.5 Hz – 1000 Hz), 10–min average - Red Channel

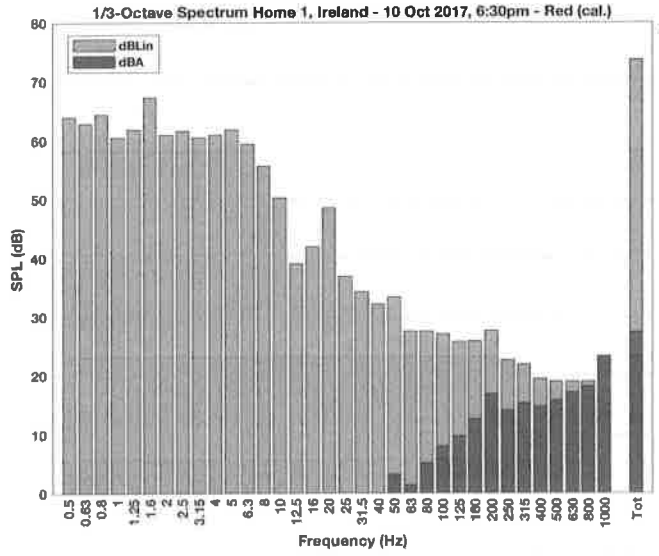

Figure 5. Data covers a 10-min interval analyzed between 0.5–1000 Hz, in 1/3-octave bands, as recorded in Home 1, on 10 Oct 2017, at 18:30 (red microphone, i.e. inside child's bedroom-2). The red bars are A-weighted values, while the gray bars indicate the acoustic energy that is, *de facto* present, in dBLin. In this environment, the human being would perceive through the ear an overall A-weighted pressure-level of approximately 26 dBA (Tot - red bar), while being simultaneously exposed to an overall acoustic pressure-level of approximately 74 dBLin (Tot – grey bar).

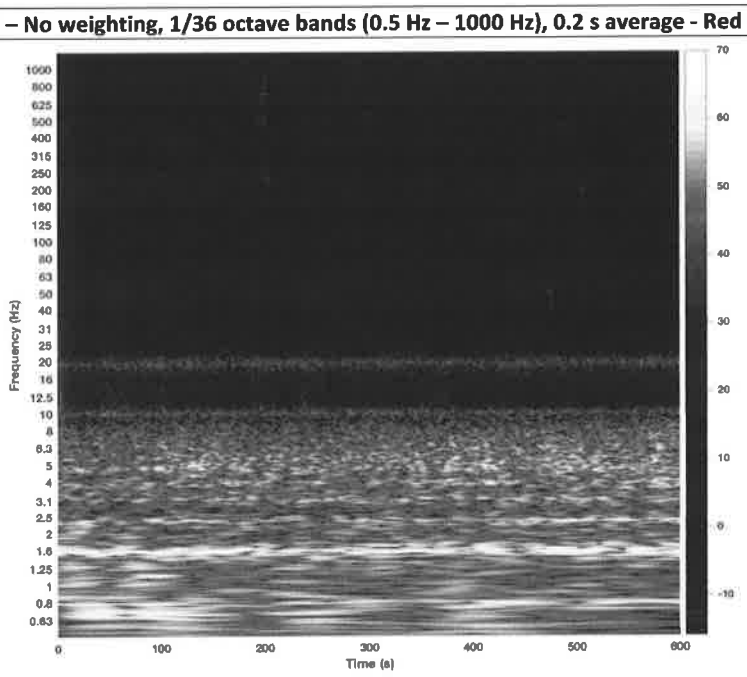

Figure 6. Sonogram that covers the same 10-min interval (600 s) as in Figures 4 and 5 showing time-varying features. The colour-coded bar on the right indicates sound pressure level values in dB Linear (no weighting). The horizontal line seen at 20 Hz is not a continuous tone because over the 600 s, its pressure level (colour-coded data) varies. A strong (yellow) acoustic phenomenon can be seen to exist at 1.6 Hz and also at 0.8 Hz.

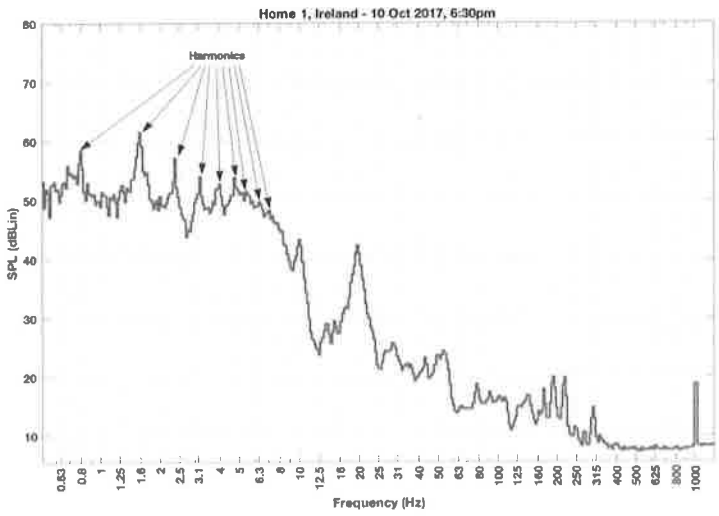

Figure 7. Periodogram covering the same 10-min interval (600 s) as in Figs 4-6, and analyzed between 0.5–1250 Hz. The blade pass frequency of the IWT is 0.8 Hz. Harmonics of this fundamental frequency are

shown in the figure. Each frequency band composing the harmonic series has a well-defined peak, e.g., the horizontal line seen in Figure 7 at 20 Hz is represented here as a peak at 20 Hz.

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26th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
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INFRASOUND AND LOW FREQUENCY NOISE GUIDELINES: ANTIQUATED AND IRRELEVANT FOR PROTECTING POPULATIONS

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Background: Over the past two decades, the increasing and unregulated production of infrasound and low frequency noise (ILFN, ≤200 Hz) has led to a considerable rise in associated noise complaints and health-related issues. The most recent of such ILFN sources are industrial wind turbines (IWT). Acoustical field-data was collected within a home located in the vicinity of IWT, to which the AUC Rule 012 and its requirements were applied. In Ontario, IWT noise complaints were gathered under the Freedom of Information legislation. **Goal:** To explore the usefulness of current noise control rules when protecting human populations against ILFN generated by IWT.

Keywords: industrial wind turbines, residential exposure, health, dBA, acoustic signatures

1. Background

The unbridled installation of industrial wind turbines (IWT) in different countries on different continents has brought a *very old problem* [1] to centre stage: the health effects induced by excessive exposure to anthropogenic (i.e., artificially generated, human-made) airborne pressure waves occurring within the lower ranges of the acoustical frequency spectrum (a.k.a. infrasound (<20 Hz) and low frequency noise (≤200 Hz), or, ILFN, given the absence of a more precise nomenclature). The goal of this report is to (yet again) emphasize the long-standing problem of anthropogenic ILFN impacting human health, this time using IWT as a source-example.

2. Industrial wind turbine 'noise' in Canada

2.1 IWT 'noise' complaints in Ontario

The government of Ontario, Canada has a process for reporting environmental pollution that offers a pollution reporting "hotline," managed by the Ministry of Environment, Conservation and Parks (MOECP), and which includes noise pollution complaints [2]. People living in proximity to IWT projects have used this service to submit Incident Reports/Complaints (IR/C) regarding environmental noise and associated adverse health effects. In order to evaluate the effectiveness of this process of reporting IWT 'noise,' government IR/C records were obtained through a request made under the province of Ontario's Freedom of Information legislation [3] by the community group coalition Wind Concerns Ontario [4].

Findings were presented during a citizen appeal of an IWT project held before the Ontario Environmental Review Tribunal [4]. Testimony included factual evidence based on the official government IR/C records submitted by residents living in proximity to operating IWT [5]. The total number of Incidents filed officially with the MOECP between 2006 and the end of 2016 was 4,574. Only 1% of the reports received a "priority" response, another 30% were deemed as "deferred," and records showed that in more than 50% of the Complaints, there was no ministry response [5]. Regarding health effects, notes by the Ministry's Provincial Officers included statements from citizens reporting "headache, sleep deprivation, annoyance, and ringing or pressure sensation in the head and ears" [5]. These health effects were reported many times, and also included children [5].

2.2 Rule 012 for Noise Control in Alberta

In the Province of Alberta, the Utilities Commission has Rule 012 [6] dedicated to *Noise Control* that encompasses "an avenue for the submission of noise complaints relating to a facility and the process for addressing noise complaints" [7]. Rule 012 imposes a limit based on a minimum basic sound level to which various adjustments are made:

Permissible Sound Level	=	Basic sound level	+	Daytime adjustment	+	Class A adjustment	+	Class B Adjustment	+	Class C adjustment

The basic sound level begins at 40 dBA L_{eq} and increases depending on the number of houses nearby and proximity of heavily travelled roads. The Daytime adjustment is an increase of 10 dBA between 7 am and 10 pm. Class A adjustments address seasonal variation and non-representative ambient monitoring. Class B adjustments are made for temporary increases in noise generation. Class C adjustments are made when the ambient wind increases to a level that masks the generated noise. On the matter of low-frequency components, Section 3.2 states: "If available, C-weighted sound pressure level (dBC) minus the A-weighted sound pressure level (dBA) is to be considered in the noise model…to identify the potential for low frequency noise impacts." The procedure then described in

Section 4.5 and Appendix 5 is required only when low frequency noise is identified subsequent to the complaint investigation. Therefore, the difference between the overall C-weighted sound level and the A-weighted sound level must be calculated for all pertinent recordings and the periodograms analysed for sharp peaks in the 20–250-hertz region. Only if both the dBC – dBA difference is greater than 20 dB *and* sharp peaks are identified, is a more comprehensive investigation of ILFN required.

3. IWT in Germany – Case Report

3.1 Background

Beginning in 2014, the Hogeveen family residing in Schleswig-Holstein, Germany, described the symptoms (to the media) that they and their children had been developing after 20 IWT were commissioned within a 2-km radius of their home [8-10]. The children—who exhibited increased aggressiveness and unexplained nosebleeds—were promptly sent to boarding school to avoid further health deterioration. The Hogeveens had to remain in the home since it is also their place of work (sports medicine and physical therapy centre), while persistently enduring dizziness, headaches, sensations of pressure on the chest and lungs, ear-aches, swollen tonsils, and ocular and oral inflammations [8-10]. But, they abandoned their upstairs bedroom and constructed a bunker-bedroom deep in the basement of the home. This has provided some respite, except when winds are easterly. Acoustical recordings were conducted simultaneously in both abandoned and bunker bedrooms, taking wind conditions into account.

3.2 Materials and methods for acoustic capture

Data were captured with a SAM Scribe FS (Full Spectrum) system (Model: Mk1, Atkinson & Rapley, Palmerston North, New Zealand) [11,12]. This two-channel recorder measures at sampling rates up to 44.1 kHz, and delivers data streams via USB to a Windows notebook computer, storing it as uncompressed wav files to hard disk. GPS information is also stored as metadata in the files, and this includes a digital signature. The manufacturer's frequency response curve shows a microphone capsule very close to linear over the 1-1000 Hz range used in this study (0.5-1000 Hz: ± 0.5 dB; 1-10 kHz: ± 2dB; 10-20 kHz: ± 4dB) (custom-made Model No.: EM246ASS'Y, Primo Co, Ltd, Tokyo, Japan) [13]. Acoustic data was processed in Matlab (The MathWorks, USA) using narrow-band filters complying with the ANSI® S1.11-2004 and IEC 61260:1995 standards. All data presented herein were captured a sampling rate of 11.025 kHz and recorded as uncompressed WAV files, including the required reference calibration tone (Type I Calibrator, 1000 Hz/94 dB). Windshields were placed on both microphones during the entire measurement periods. Microphones were attached to tripods at approximately 1.5 m above the ground. The recordings selected for analysis and presentation herein were chosen on their educational value, and are shown in Table 1.

Table 1: Samples selected for analysis and presentation herein.

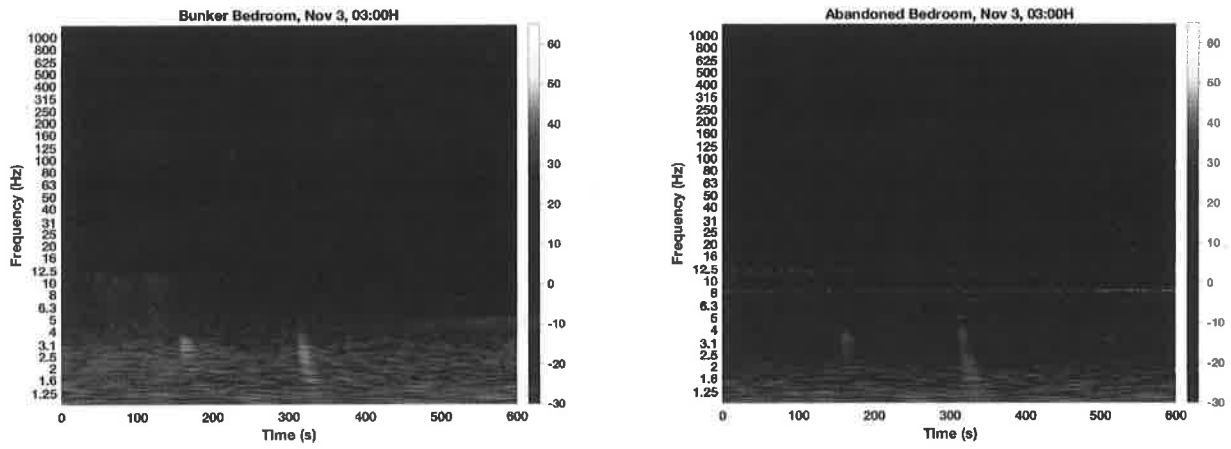
Sample	Date	Time	Wind Speed (m/s)	Wind Direction
Lo wind	03NOV17	03:00	0.9	290°
Hi wind	01NOV17	14:00	7.6	290°

3.3 Abandoned vs. Bunker bedrooms

Significant and distinctive differences were found between the two environments that survived changes in wind speed and wind direction. Figure 2A-D compares the sonograms of the simultaneous recordings captured in both locations, under both wind speeds. All disclose some tonal components (horizontal lines) although these appear more prominent in the abandoned bedroom than in the bunker bedroom. The abandoned bedroom discloses larger SPL values between approximately 5-40 Hz in low wind conditions (0.9 m/s, Fig. 2B), and between 6.3-40 Hz in the high-wind conditions (7.6 m/s,

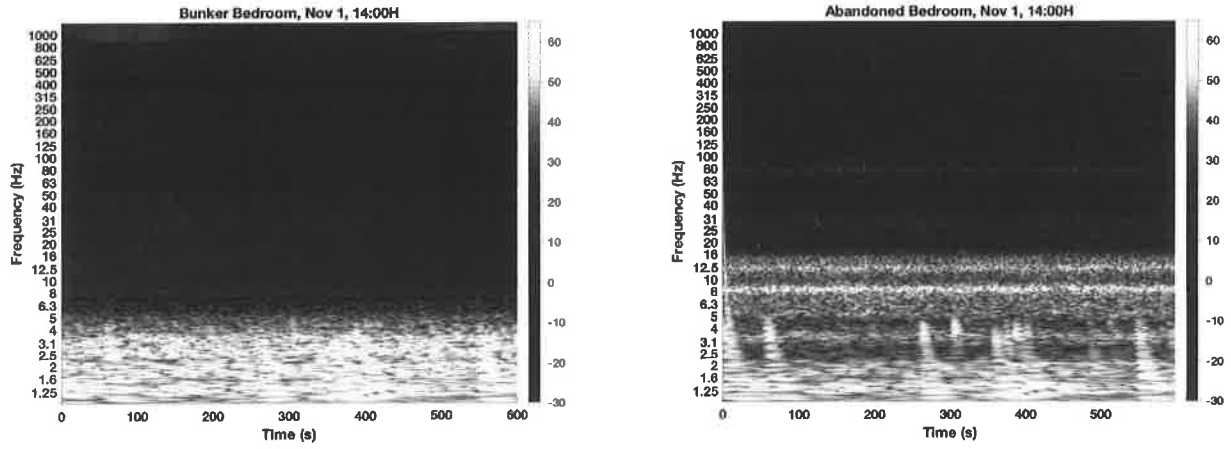
Fig. 2D). Within those frequency bands, distinct peaks at 8 and 12 Hz, as well as a peak at 80 Hz, are present in the abandoned bedroom, but absent from the bunker bedroom. Apart from some wind-gust noise—seen as vertical features broadening and moving to the right with decreasing frequency—the sonograms tend to show that the character of the sound does not change throughout the 10-minute periods and so the periodograms, shown in Figure 3, are representative of the sound over those intervals. (The continuous, 1000-Hz tone seen in the quieter recordings is due to electronic noise within the SAM Scribe Mk1, eliminated in the more recent SAM Scribe models.)

Wind speed 0.9 m/s and westerly wind (290°) on 03 Nov 2017, at 03:00H.



A. Bunker bedroom. **B.** Abandoned bedroom.

Wind speed 7.6 m/s and westerly wind (290°) on 01 Nov 2017, at 14:00H.



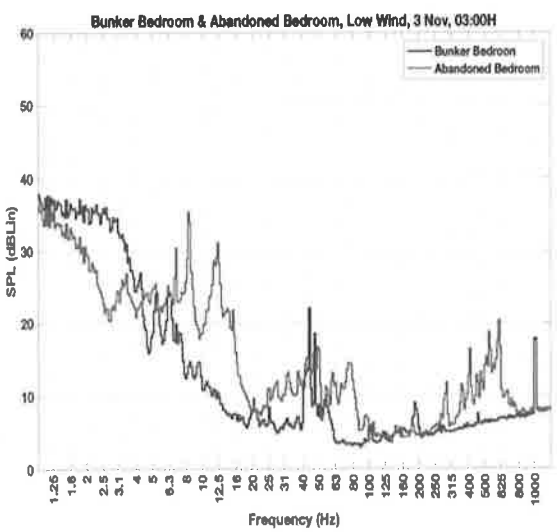
C. Bunker bedroom. **D.** Abandoned bedroom.

Figure 2: Sonograms covering a 10-min interval (600 s) and analyzed between 1–1250 Hz. The color-coded bar on the right indicates SPL in dBLin.

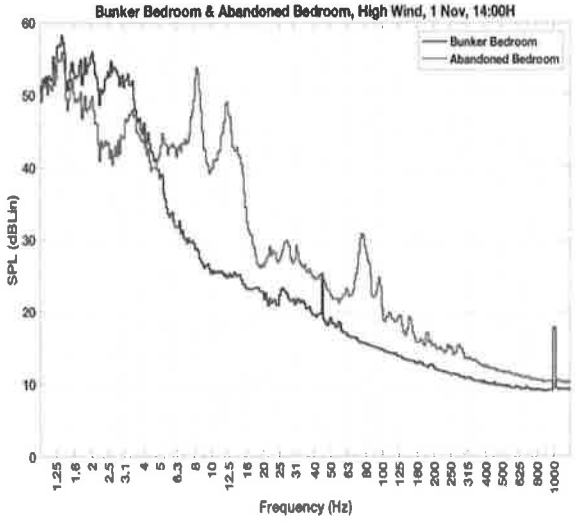
In the abandoned bedroom, the shapes and positions of the peaks at the three frequencies (8, 12 and 80 Hz, Fig. 3) are quite distinct, are clearly identifiable and independent of wind speed. Particularly visible in Fig. 3 is the similarity in the profile, occurring simultaneously in both locations, at the lower limiting frequencies of these measurements, i.e., approximately from 0.1 Hz to 2.5 Hz or to 4.5 Hz. The acoustical events responsible for these readings seem to impact both locations in the same manner, independent of wind conditions. The wavelengths corresponding to the airborne acoustical events at

these frequency values are, approximately, 76 m (4.5 Hz) to 3430 m (at 0.1 Hz). The source of these phenomena remains unclear.

At low wind speed (0.9 m/s), the bunker bedroom displays a continuous tone at approximately 50 Hz. This can be seen as a horizontal line in the sonograms (Fig. 2A and 2C), as peaks in the classical analysis (Fig. 4), and as narrow peaks in the corresponding periodogram (Fig. 3). Usually, these tones are attributed to electrical appliances that may be present in the environment, and that do not vary with wind conditions. This is much less obvious in the abandoned bedroom (Fig. 2B and 2D) since no appliances are currently present. In the abandoned bedroom, tones that are not present in the bunker bedroom can be identified at 8 Hz, 12.5 Hz and 80 Hz (Fig. 3). These tones are present at low wind speed and increase in sound pressure level with higher wind speeds, while maintaining the consistency of their shape.



A. Bunker vs. Abandoned bedrooms. Wind speed 0.9 m/s, westerly wind (290°), 03 Nov 2017, at 03:00H.



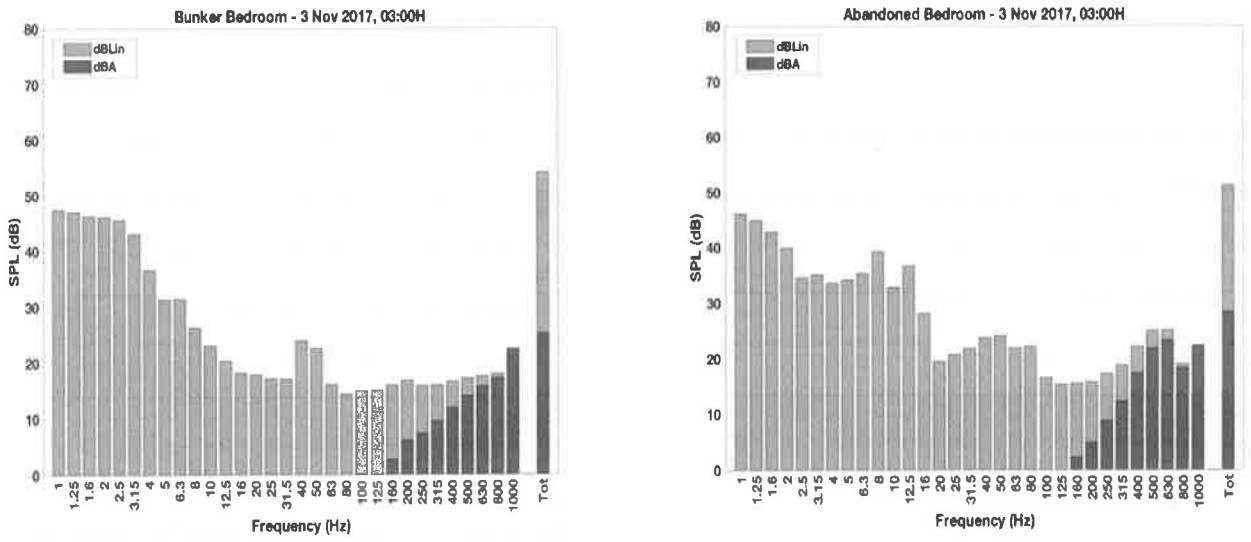
B. Bunker vs. Abandoned bedrooms. Wind speed 7.6 m/s, westerly wind (290°), 01 Nov 2017, at 14:00H

Figure 3: Periodograms covering the same 10-min intervals as in Figure 2 (analyzed between 1–1250 Hz), comparing the bunker and abandoned bedrooms at low and high wind speeds. The abandoned bedroom has consistently higher SPL levels than the bunker bedroom within the 4-40 Hz range, with very distinct shapes. At the lowest frequencies (≤2 Hz), SPL variations in both rooms have similar shapes and positions.

4. Discussion and Conclusions

Figure 4 shows ⅓-octave analyses obtained from a 10-min average, corresponding to the period shown in Figure 2A-B. In the bunker bedroom, the unweighted SPLs (Fig. 4A, grey bars) show a broad peak at about 50 Hz (or two narrower peaks on slightly either side). The highest SPLs are recorded below about 4 Hz. Unweighted SPLs in the abandoned bedroom (Fig. 4B, grey bars) show peaks at 8 and 12.5 Hz. There is relatively more energy in the abandoned bedroom above 4 Hz, but less below this. In both cases A-weighted SPLs (red bars) merely reflect that which humans would *hear* if present. As per Rule 012, this is the type of data required to establish permissible exposure levels.

Rule 012 was informally applied to the data obtained from the Hogeveen home. No recordings were made outside of the residence so the interior recordings used would a) be quieter than outside recordings and b) have a higher proportion of ILFN. The basic sound level is the lowest, 40 dBA, since it has less than 9 nearby dwellings within a 451-metre radius and is further than 500 m from a heavily travelled road. (Since outside night-time levels in the absence of IWT were impossible to measure, a 35-dBA level is assumed for the remainder of these calculations.)



A. Bunker Bedroom.

B. Abandoned bedroom.

Figure 4: These ⅓-octave frequency histograms cover the same 10-min interval as shown in Fig. 2A and B, wind speed 0.9 m/s and westerly wind (290°) on 03 Nov 2017, at 03:00H.

Two Class A adjustments are required. Assuming that a complaint is made in wintertime (the season during which these recordings were made), there is a +5 dBA adjustment. The ambient sound level with operational IWT is already 5 dBA below the basic sound level of 40 dBA, therefore, the adjustment is the maximum of +10 dBA. Since the sum of these two is +15 dBA, the maximum possible of +10 dBA is taken. For the Class B adjustment, two cases were considered: no increase occurs and one increase occurs for up to 60 days. This will give an adjustment of 0 dBA for the first case and +5 dBA for the second. The night time limit is therefore 40 dBA + 10 dBA + 0 dBA = 50 dBA for the base case, and 55 dBA is permissible for one period a year of up to 60 days. The daytime limit is the night-time value + 10 dBA = 60 dBA. The C-weighted and A-weighted overall sound levels for the 10-minute intervals captured on 01 and 03 November are shown in Table 2.

Table 2: dBC-dBA applied to the German data

	dBA Leq 10-min	**dBC Leq 10-min**	**Difference**
Bunker bedroom (01Nov)	35.7	56.2	20.5
Abandoned bedroom (01 Nov)	39.4	60.9	21.5
Bunker bedroom (03 Nov)	30.9	39.9	9.0
Abandoned bedroom [03 Nov)	33.7	42.7	9.0

Since these aspects of Rule 012 are stipulated in A-weighted sound levels, and the controversial features of IWT emissions are all in the ILFN regions, it is not surprising to find that these thresholds would very rarely be breached by IWT. The conclusion is that these aspects of Rule 012 are largely irrelevant. Moving, then, to the sections of Rule 012 dealing with ILFN, the question of whether significant components exist is determined by section 3.2 [7]. The difference in C-weighted and A-weighted sound levels must be 20 dB or more *and* there must be prominent, sharp peaks between 20 and 250 Hz. Figure 3 shows that there are prominent, sharp peaks in the bunker bedroom (blue lines) between 40 and 50 Hz. The abandoned bedroom does not show sharp peaks, therefore, they are not considered tonal, even though they are prominent. From the differences in the C-weighted and A-weighted sound levels, it can be seen that only the recording made on November 1, with high wind speeds, exceeds the 20-dB threshold. Ironically, this is because of the increased wind noise in the

ILFN regions. Section 4.5 (4) however, states that measurements should not be taken during high-wind-speed conditions for exactly this reason. Therefore, this aspect of the Rule also fails to catch the important soundscape features. Had it done, and the requirements of section 4.5 were met, the maximum penalty would be the addition of 5 dBA to the measured sound levels. If these then exceeded the limits (between 50 dBA and 60 dBA as above) then the operator would be required to implement noise attenuation measures and confirm that ILFN was no longer an issue.

When IWT are the source of ILFN, the rotating blades generate a series of pressure pulses at the 'blade pass frequency' (BPF), which is seen as a harmonic frequency series called *wind turbine signature* [14]. When synchronous IWT rotate at a constant rate, regardless of the wind speed, they will share a common harmonic series [15]. The IWT near the Hogeveen home are asynchronous, their BPF changes with wind speed. Given the sheer number of these IWT at the site, a single ('clean') IWT signature was not a reasonable expectation. Nevertheless, an analysis of the existence of harmonic series was conducted on the recordings of the abandoned bedroom, at low and high wind speeds.

Figure 5 shows the 1–100-Hz region of Fig. 3 with the harmonic series starting at 1.36 Hz added as dashed lines. The two main peaks at 8 and 12 Hz appear on this harmonic series as the 6th and 9th harmonics (H6 and H9). There is a large peak at 1.36 Hz for the higher wind speed. The 8 and 12 Hz peaks also appear on the harmonic series starting at 2.04 Hz; there is a small peak at 2.04 Hz. There is also a peak at 6.8 Hz on this series for the lower wind speed. A further harmonic series starting at 0.68 Hz includes these three peaks (1.36 Hz, 2.04 Hz and 6.8 Hz) as well as the broad peak at 3.45 Hz. There is no suggestion that peaks have moved between the two wind speeds although neither of the peaks (1.36 and 2.04 Hz) is seen at the lower wind speed. Note that the resonant frequencies of the bedroom are in the order of 60 Hz and upwards, with the peak just below 80 Hz likely being one such. The peaks discussed above are therefore less than $^{1}/_{10}$ of the cavity resonant frequencies and are not likely to be attributable to these phenomena.

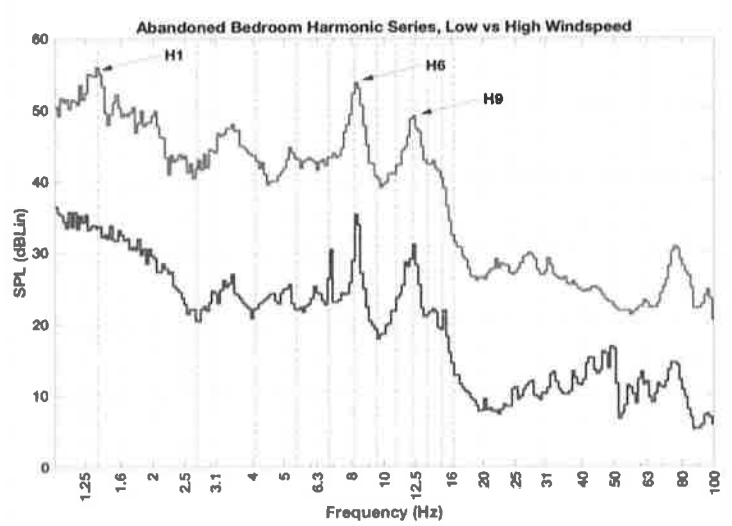


Figure 5: Comparison of data captured in the abandoned bedroom, at low (0.9 m/s-blue) and high (7.6 m/s-red) wind speeds, and same wind directions (290°). Harmonics of 1.36 Hz are shown as vertical, dashed lines.

A re-evaluation of legislation regarding population exposure to ILFN has been urgently required for decades [1]. The Canadian regulations here applied are similar to other regulations worldwide, and equally unsuitable *if* the goal is to protect human health against chronic ILFN exposures. Symptomatic complaints currently being ignored and/or misdiagnosed will predictably lead to a burden on future healthcare costs. Although the proliferation of IWT is bringing this agent of disease [16] to centre stage, the biases regarding how human health is impacted by airborne pressure waves (audible or not and whatever the source) continue to impede a proper scientific investigation [17], and consequently, proper protection of human populations and their offspring.

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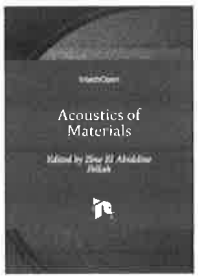
CHAPTER SUMMARY

Acoustics and Biological Structures

M. Alves-Pereira, B. Rapley, H. Bakker, R. Summers



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This chapter consolidates what is known to date of the biological effects of airborne pressure waves occurring within the infrasonic and lower frequency ranges of the acoustical spectrum, and that are commonly referred to as infrasound and low frequency noise (ILFN).

In the **Introduction**, three reasons are given as to why there is a shortage of studies that properly evaluate the biological response to ILFN:

1) The rudimentary segmentation of the acoustical spectrum, as shown in Figure 1 (compare to the much greater segmentation of the electromagnetic spectrum);
2) The inappropriate use of the dBA metric to quantify ILFN, as explained by Figures 2-4; and
3) The indoctrinated, but scientifically indefensible, notion that "what you can't hear can't hurt you".

The basic principles related to biomaterials as related to ILFN exposure are provided in the section **Biomaterials and Human Anatomy**. The viscoelastic properties of biological materials impart a non-linear response to biological outcomes. Knowledge on cellular and tissue architecture, as well as on the basic human anatomy of the fasciae, can provide insight as to how airborne pressure waves can cause lesions in biological tissues, leading to clinically verifiable pathology.

The subsequent section, **Laboratorial Studies, Field Studies and Biological Outcomes**, describes the three most prevalent study setups: laboratory and field-laboratory studies within occupational or residential environments. Advantages and disadvantages of each type of experimental setup are explored.

In Laboratory studies:

a) Acoustic parameters can be precisely quantified and varied;
b) Exposure time can be precisely controlled;
c) There are numerous biological outcomes that can be examined.

In Occupational field-laboratories:

a) Acoustic parameters can be quantified but not varied in a scientifically controlled manner.
b) Concomitant non-occupational exposures (after the end of the workday) must be accounted for.
c) Prior ILFN exposures (fetal, childhood, adolescence) must be tallied.
d) The type of biological outcomes that can be explored are much more restricted.

In Residential field-laboratories:

a) Acoustic parameters are more difficult to quantify because, typically, they vary more with time than in occupational field-laboratories.
b) All areas internal and external to the residence must be acoustically characterized.

c) Concomitant ILFN exposures occurring outside of the home (occupational, recreational) must be accounted for.
d) Prior ILFN exposures (fetal, childhood, adolescence) must be tallied.
e) The types of biological outcomes that can be explored are very limited.

Specific biological outcomes in ILFN exposed humans and animal models are described in Section 4, **Past Relevant Studies**. Specifically,

1) Vascular structures,
2) Collagen and connective tissue,
3) Heart cells and tissues, and
4) The hippocampus region of the brain.

Vascular structures
Under ILFN exposures, the demands of the organism's blood flow can be substantial, leading to the development of twisted and tortuous arteries in the ocular (Table 1) and gastric structures, in both human and animal models. This could partially explain the reduced vision acuity reported in ILFN-exposed individuals, as well as the gastrointestinal complaints documented in citizens living near airports, or in "noise-exposed" industrial workers. Hemorrhagic events and other vascular abnormalities were observed in respiratory system structures in animal models, and in humans exposed to occupational or residential ILFN (Table 2).

Collagen and connective tissue
Collagen is considered to be the steel of the human body. Under long-term ILFN exposure, there is an increased production of collagen in the vascular and respiratory system structures than can manifest as clinical symptoms. This feature is partially explained by the architectural and viscoelastic properties of biomaterials, as explained in Section 2.

Heart cells and tissues
ILFN exposed individuals commonly report heart arrhythmias. Laboratory studies have shown that conditions associated with ventricular arrhythmias develop in animals exposed to ILFN. Additionally, cardiomyocytes exposed to ILFN developed abnormal structures that persisted much time after ILFN exposure ceased.

The Hippocampus
Learning and memory impairment develops in animals exposed to ILFN. It has been shown that ILFN-induced neuronal death can occur in the hippocampus, and can therefore be responsible for the observed cognitive deficits (unrelated to sleep disorders).

In **Conclusion**, exposure to infrasonic and lower frequency airborne pressure waves can cause cellular and tissue damage depending on frequency, dB-level, and exposure time, while the viscoelastic properties inherent to biological tissues impart a nonlinear response to this type of acoustic stressor. The underlying objectives of most of the studies discussed herein are related to occupational exposures and do not consider continuous exposures at less than 90 dB, nor are pressure pulsed trains presented within the laboratorial acoustic environments. In residential environments however, these attributes are often present. The simulation of residential exposures does not appear to have yet been integrated into laboratory settings and protocols. The whole-body response also elicits the immune system, affects organs of the reproductive system, changes receptor cells in the vestibular semi-canals and auditory cochlea, and induces genotoxic effects, including teratogenesis. This is a pioneering field of science, still in its infancy and urgently requiring scientists from multi-disciplinary areas of study because, ultimately, the health of human populations and their offspring must be protected.

Chapter

Acoustics and Biological Structures

Mariana Alves-Pereira, Bruce Rapley, Huub Bakker and Rachel Summers

Abstract

Within the context of noise-induced health effects, the impact of airborne acoustical phenomena on biological tissues, particularly within the lower frequency ranges, is very poorly understood. Although the human body is a viscoelastic-composite material, it is generally modeled as Hooke elastic. This implies that acoustical coupling is considered to be nonexistent at acoustical frequencies outside of the human auditory threshold. Researching the acoustical properties of mammalian tissue raises many problems. When tissue samples are investigated as to their pure mechanical properties, stimuli are not usually in the form of airborne pressure waves. Moreover, since the response of biological tissue is dependent on frequency, amplitude, and time profile, precision laboratory equipment and relevant physiological endpoints are mandatory requirements that are oftentimes difficult to achieve. Drawing upon the viscoelastic nature of biological tissue and the tensegrity model of cellular architecture, this chapter will visit what is known to date on the biological response to a variety of different acoustic stimuli at very low frequencies.

Keywords: infrasound, low frequency noise, health, cellular biology, tissue morphology

1. Introduction

Airborne pressure waves are ubiquitous in all human environments and have played vital roles in the survival, evolution, and development of the human species. Under certain conditions, airborne pressure waves can be perceived as "sound" by the human auditory system. Under other conditions, they may be perceived as a whole-body or partial-body vibration. Some airborne pressure waves are not consciously perceived at all. As human societies developed and became more technological, airborne pressure waves emanating from human-made devices became ubiquitous and "noise" became a more serious issue. By the late nineteenth century, noise and health studies began to flourish. In the early twentieth century, the telephone and growing industrialization led to more in-depth studies of the human hearing function. In 2011, a WHO document on the burden of diseases reflected the seriousness of the ongoing "noise problem" [1].

The only airborne pressure waves considered of consequence for human health were those that could be *heard*, i.e., "what you can't hear can't hurt you" (**Figure 1**). This notion justified the development of acoustic measuring devices and methodologies that concentrated solely on the audible portion of the acoustical spectrum.

Within the audible segment (20–20,000 Hz), human auditory acuity is not evenly distributed, and is more sensitive within the 800–7000 Hz range than it is to airborne acoustic events occurring below 500 Hz or above 15,000 Hz. Thus, early on, scientists understood that in order to protect human hearing function and speech intelligibility, the entire audible segment need not be considered, but rather, only the frequencies at which the acuity was highest: 800–7000 Hz range. The development of the A-frequency weighting and the resulting deciBel-A (dBA) metric allowed acousticians and health professionals to assess acoustical environments simulating this variability of human auditory acuity.

Figure 2 shows the frequency response curve for the dBA metric, clearly following the human auditory response to airborne acoustic pressure waves.

While the dBA metric proved to be key for the protection of hearing and speech intelligibility, it was insufficient for the assessment of airborne pressure waves occurring outside of the 800–7000 Hz range. **Figure 3** emphasizes the 800–7000 Hz range within the dBA metric, and **Figure 4** shows its application at 10 Hz. The dBA metric is, therefore, unsuited for evaluating airborne pressure waves occurring at frequencies below 800 Hz. Health effects that may be developing due to exposures

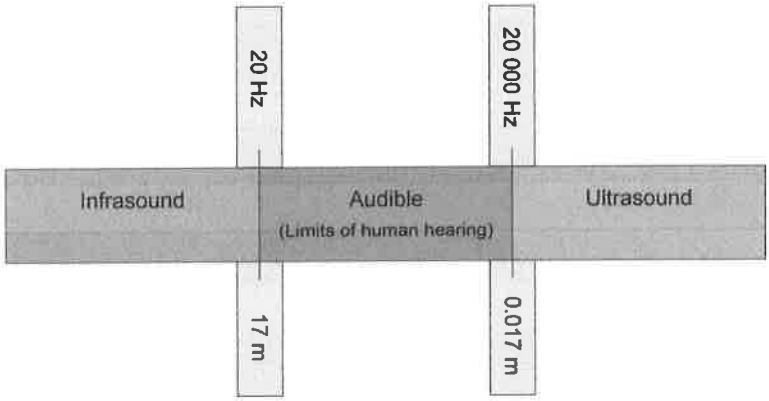

Figure 1.
Acoustical spectrum showing the classical three segments (infrasound, audible, and ultrasound) with the frequency and wavelength indicated at the cutoff of each segment.

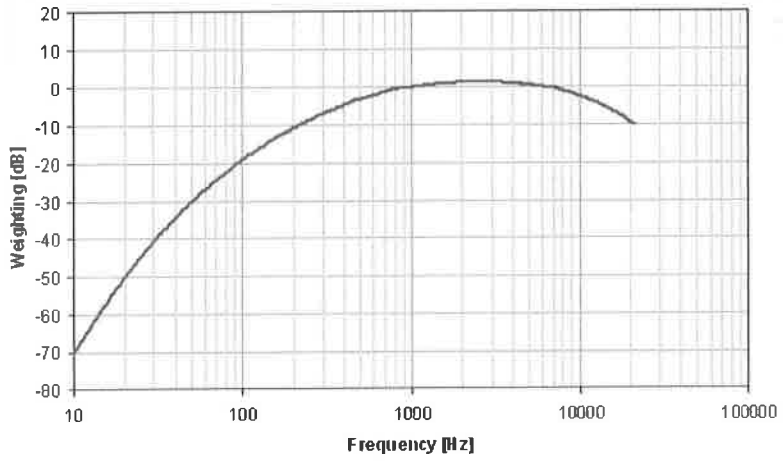

Figure 2.
Frequency response curve for the deciBel-A metric (dBA) commonly used in noise-related legislation [2].

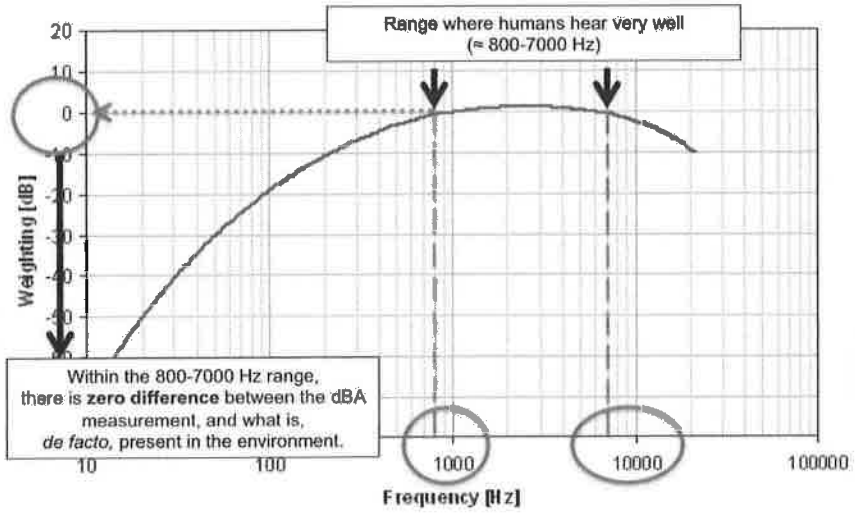

Figure 3.
Frequency response curve for the dBA metric applied to the range of highest human auditory acuity. Within this frequency range, the dBA measurement will accurately reflect the airborne acoustical energy present in the environment.

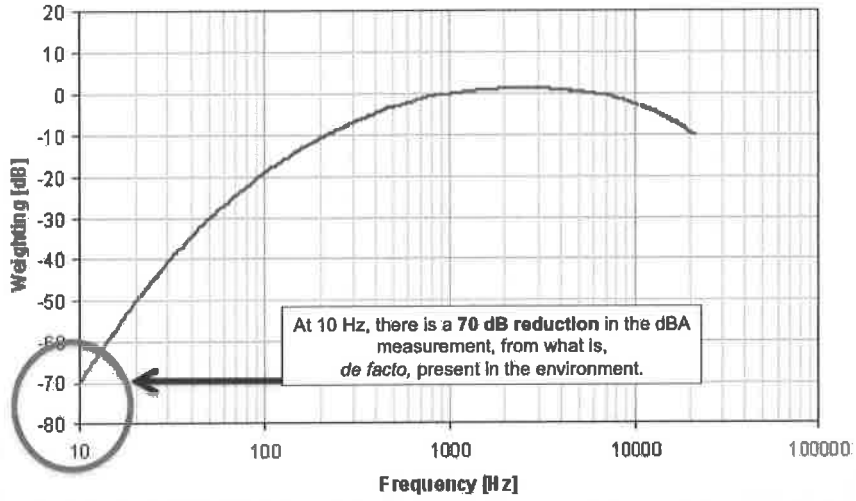

Figure 4.
Frequency response curve for the dBA metric applied to infrasonic frequency ranges, showing a 70 dB difference when evaluated at 10 Hz. Within these lower frequency ranges, the dBA metric will significantly underestimate the airborne acoustical energy present in the environment.

at these lower frequencies cannot be properly studied if the dBA metric is being used to characterize acoustical environments.

There is a shortage of studies that properly evaluate the biological response to infrasonic (≤20 Hz) or lower frequency (≤200 Hz) airborne pressure waves. Three important reasons for this have been provided above: the rudimentary segmentation of the entire acoustical spectrum into merely three "blocks" (compare to segmentation of the electromagnetic spectrum), the unsuitability of the dBA metric to quantify airborne acoustical pressure waves at these lower frequencies, and the ingrained notion that "what you can't hear can't hurt you." These major hindrances have been crystallized into mainstream science [3] and have served to significantly impede scientific inquiry and human health protection.

The goal of this chapter is to consolidate what is known on the biological response to airborne pressure waves occurring within the infrasonic and lower frequency ranges. A biomedical engineering approach is taken, whereby biological organisms are viewed as structures of composite materials, with significant viscoelastic components and organized in accordance with the principles of tensegrity architectures. When airborne pressure waves impact these types of structures, the biological response will depend on the type of biomaterial under study, it will exhibit anisotropic properties, and it will vary nonlinearly with exposure time. Depending on the physical properties of the airborne pressure waves (including time profiles) and on the biostructure under study, mechanical perturbations are relayed into cells and tissues through a variety of different pathways that, to date, still remain unclear.

2. Biomaterials and human anatomy

2.1 Viscoelasticity

Viscoelasticity is an attribute given to bodies that exhibit both viscous and elastic behaviors beyond the classical Hooke's elastic model [4]. Viscoelastic materials have three distinct properties not contemplated by Hookean models: creep, stress relaxation, and hysteresis. Most biological materials have viscoelastic behaviors.

In a Hookean (or purely elastic) material, total deformation depends on total load, and no further deformation occurs even if load is maintained. In viscoelastic materials, however, when sufficient stress is applied and maintained, they may continue to deform, even though stress load remains unaltered. This property is called *creep*.

In a purely elastic material, the strain within the material is constant throughout the application of the load; it does not vary with time, but only with the amount of applied stress. In viscoelastic materials, when stress is applied and maintained, strain can decrease with time. This property is called *stress relaxation*.

Consider repetitive or cyclical loads on materials. In purely elastic materials, periodic loads will not alter the stress-strain curve. The pathway taken by the material to deform is exactly the same pathway it takes to return to its original, equilibrium position. In viscoelastic materials, however, the return to equilibrium may be different than the pathway used to get to the point of deformation (The word pathway is here loosely used, and is meant to encompass all spatial, temporal and energetic components of these types of movements.) This property is called *hysteresis*.

2.2 Tensegrity structures

Many structures in the natural world are organized in accordance with the principles of tensegrity architecture—elements providing discontinuous compression are held together through elements of continuous tension [5]. **Figure** 5 shows several examples of tensegrity structures.

Depending on the properties of the airborne pressure waves and biomaterial under study, the propagation of mechanical perturbations throughout these types of structures can reach long distances, without loss of structural integrity.

2.3 Cellular and tissue mechanotransduction

Cells and tissues are organized in accordance with the principles of tensegrity architecture [8, 9]. This means that in addition to biochemical signaling,

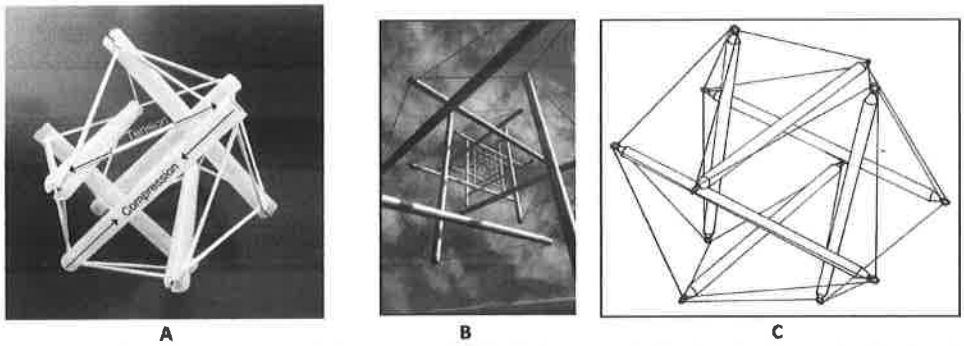

Figure 5.
Tensegrity structures. A. Model showing elements of continuous tension and discontinuous compression. B. Needle tower, by Kenneth Snelson, in the Hirshhorn sculpture garden (USA) [6]. C. Icosahedron, first designed by Buckminster Fuller in 1949 [7].

cells also communicate with their surroundings through mechanical signals. Mechanosensitive receptors exist on cell surfaces, and mechanosensitive junctions interconnect cells, thus forming tissues. Depending on the physical properties of the airborne pressure waves and biomaterials under study, external airborne mechanical perturbations can elicit a mechanical response, which, in a larger, macroscopic view, can lead to clinically pathological situations.

2.4 The fasciae

The fascia is a sheet of connective tissue that uninterruptedly extends from head to toe, suspended from the skeleton, and that provides the integrated supporting framework for maintaining anatomical and structural form [10, 11]. That external mechanical perturbations elicit responses at large distances away from the point of entry is a well-known concept among scientists and health professionals who study fasciae. When presented with external airborne pressure waves, fasciae can respond by changing their structural properties: *from a mechanical point of view, the fasciae are organized in chains to defend the body against restrictions. When a restriction goes beyond a specific threshold, the fasciae respond by modifying their viscoelasticity, changing the collagenic fibers, and transforming healthy fascial chains into lesioned chains* [10]. One of the fascia's key roles is that of shock absorption.

Connective tissue structures are ubiquitous forming all external surfaces of vessels, nerves, organs, and muscles, and at the cellular level, the extra-cellular matrix that surrounds and communicates with each individual cell. In addition to maintaining structural integrity, the fasciae are the first line of defense against external perturbations, playing important physiological roles in mobilizing the immune system.

3. Laboratorial studies, field studies, and biological outcomes

Studying the effects of infrasonic or lower-frequency airborne pressure waves on biological structures is a very complex undertaking, whether it be on cell cultures, on animal models, or on human populations. Laboratorial studies, occupational field studies, and residential field studies all have their own strengths and weaknesses. When the latter go unrecognized, however, experimental design flaws can ensue. In this section, the attributes of these different experimental setups are discussed, and their weaknesses and strengths are explored. Together

with the preceding section, this serves as a preamble to Section 4, where the results of experimental studies are described in detail.

3.1 Laboratorial studies

Laboratories where infrasonic and lower frequency airborne pressure waves can be applied in a controlled manner are in short supply worldwide, and those that do exist are mostly associated with military installations. Laboratories emitting airborne pressure waves with infrasonic and lower frequency components cannot be randomly placed within residential environments; issues with neighbor disturbance and public health would curtail its use. Moreover, the equipment used to generate the airborne pressure waves is, typically, very large and very expensive, and few sectors of society (other than military or space exploration industries) would have the need for an extensive use of these types of installations.

In these laboratory settings, continuous or pulsed-trains of single-tone airborne pressure waves can be applied, as well as, broadband exposures that can be accurately characterized. The fact that exposure times and acoustic parameters can be precisely controlled is one of the strengths of laboratorial studies, allowing for continuous time exposures, or occupationally simulated exposure schedules. Immediate (hours or days) versus long-term (weeks or months) effects can also be explored.

There are numerous types of biological outcomes that can be studied under laboratorial conditions. Light-, electron- and atomic-force microscopy can be used to study cellular and tissue structural properties, as well as their chemical composition and content of bio-reactive elements. Polymerase chain reaction (PCR) techniques can provide information on messenger RNA (mRNA) expression, allowing for the identification of key pathways. With pharmacological intervention or gene knock-out specimens, specific signaling molecules and pathways involved in the elicited responses can be pinpointed. Additionally, control populations for comparison are fairly easy to achieve—they are simply not subjected to the laboratorial exposures.

3.2 Occupational field laboratories

Occupational environments are exceptional field laboratories, as both short-term (several months) and long-term (years) effects can be investigated in more realistic acoustic environments. Typically, different workstations have different acoustical features that can greatly depend on different machinery regimens. For occupational field laboratories, acoustical characterizations of the workplace(s) must be comprehensively undertaken and time exposures to each type of environment should be scored.

Exposure times at work must be differentiated from exposure times away from work, i.e., when the work shift ends, workers leave the field laboratory, but additional exposures to infrasonic or lower frequency airborne pressure waves may be incurred (e.g., recreational, transportation). These must be documented. Significant confounding factors may be introduced unless each subject's residential area is scrutinized and prior-exposure histories probed for fetal, childhood, and adolescent exposures.

Possible biological outcomes within occupational field studies are more limited when compared to laboratory exposures. Noninvasive testing can be imprecise, and the minimally invasive testing (such as a blood chemistry analysis, X-ray, or MRI) may also not be sufficiently precise to yield relevant data. It is also the case that scientific knowledge on relevant biological outcomes that can be noninvasively evaluated in exposed humans is still absent or, at best, very incomplete.

Survivorship bias is a well-known confounding factor in human population studies. In occupational environments, workers with more time on-the-job are those who have survived throughout the years of professional activity, while workers with less time in professional activity may exhibit more severe biological outcomes. This phenomenon is often misinterpreted leading to inconclusive or erroneous conclusions.

Control populations for exposures to infrasonic and lower frequency airborne pressure waves have been a very difficult proposition, given the ubiquitous nature of this stressor. One of the solutions to this profound problem is the scoring of subjects into different groups as per their exposure. Within this context, control groups are composed of individuals who have the least amount of cumulative (prior and present) exposure, and not of individuals with zero exposure.

Different professions can provide different field laboratories, both in terms of acoustic environment and time exposure schedules. For example, long-haul truck drivers are typically exposed for more than 8 hours daily and, oftentimes, sleep in the truck while it is idling, or while refrigeration systems are continuously operating. Workers onboard ships, submarines, offshore oilrigs, aircraft, and spacecraft (for example) can be exposed to significant amounts of infrasonic and lower frequency airborne pressure waves for weeks or months at a time. The wealth of information waiting to be gleaned from these types of field laboratories is breathtaking.

3.3 Residential field laboratories

Field laboratories in urban, suburban, and rural residential settings are generally designed to investigate environmental health effects due to human-made infrasonic and lower frequency airborne pressure waves. Typically, these sources are associated with industrial complexes or infrastructure that, in turn, are usually linked with important economic interests. In general, the amount and type of infrasonic and lower frequency airborne pressure waves contaminating a home will depend on the machine operation and/or the use of the infrastructure. For example, in most urban and suburban areas, airports must close down between the hours of midnight and 5 am. Some factories do not have night shifts and therefore also have daily shutdown periods. Large refrigeration units, hydroelectric dams, and large volume highways, however, must be kept running 24/7 and can also be viewed as continuous sources of infrasonic and lower frequency airborne pressure waves. Wind turbines are the latest addition to these type of sources although they are almost exclusively within rural areas.

Comprehensive characterization of the acoustic environments in the different residential areas must be undertaken (e.g., master bedroom, children's bedrooms, living-lounge areas), since room-resonance phenomena can significantly modify the acoustic environment that is originally being induced and driven by external, incoming airborne pressure waves. Additionally, wind can also influence the spectrum, intensity and type of infrasonic and lower frequency airborne pressure waves that exist within a room. This differentiation is readily achieved with proper acoustic evaluations.

Residential exposure times are much more difficult to control, as they can differ from room to room and on an hourly basis. Moreover, subjects may also be sleeping within the "contaminated" environments, which can severely aggravate biological outcomes. If exposure is concomitantly occurring during sleep and waking hours (e.g., homemakers, workers from home, farmers), then biological outcomes may be further aggravated. Leaving the home can be equated with a biological recovery period (i.e., nonexposure period).

Short-, medium- and long-term effects can be studied in residential settings when the implementation of a new infrastructure or industrial complex is known to be coming to the area. Biological outcomes should strive to be either noninvasive or minimally invasive, and prior-exposure histories are fundamental for achieving useful statistical data.

4. Past relevant studies

Numerous studies conducted over the decades have shed light on the biological response to infrasonic and lower frequency airborne pressure waves and associated symptomatic complaints. Due to space limitations, this discussion will only deal with some of the vascular and collagenous abnormalities, cardiomyocyte changes, and the hippocampus responses, as induced by different types of exposures. For reasons explained in the section "Introduction," all studies using the dBA metric have been eliminated from consideration (with one exception in an occupational setting). Selected studies mostly focus on the cellular and tissue changes observed in laboratory, occupational, and residential settings, using light and electron microscopy. The sequence in which the studies are presented does not follow the classical anatomical order.

4.1 Vascular changes

In the mid-1960s, within a military setting, the immediate exposure to 10–60 Hz, at 118–140 dB, for 2 minutes, induced disturbances of the visual field as reported by all five human subjects [12]. In 1985, laboratorial animal studies exposed rats to tonal 8 Hz at 100–140 dB, 3 hours daily, for 5, 10, 15, or 25 days, and examined the blood and lymph networks of the palpebral (eyelid) and bulbar (eye globe) conjunctiva. *Day 5*: narrowing of all parts of the conjunctiva blood network was observed, with decreased blood capillary lumens. Capillaries, precapillaries, and arterioles were twisted, and blood component agglomerations were identified in venous vessels. *Day 10*: conjunctiva capillaries were twisted and large vessel diameters were decreased. *Day 15:* blood and lymph vessel tonus had changed, and stagnation was present. *Day 25:* failure of tissue homeostasis was aggravated. Capillary penetration was increased, as seen through tissue enlargement, and significant agglutination was observed in the large vessels [13].

In a similar study, animals were exposed to 8 Hz at 100 dB, or to 16 Hz at 100 dB, 3 hours daily, for 1 month. Clinical and morphological evaluations were conducted at days 3, 7, 15, 30, and also post-exposure at days 30, 60, and 90. *Day 3:* clinical changes were not observed, but morphological changes were present: edema in the upper and middle areas of the eyelid derma and heterogeneous blood filling of vessels with extra-vascular erythrocytes were also observed. Fine focal hemorrhages were identified under the corneous layer of the eyelid. Sclera exhibited edema, and blood vessels were filled heterogeneously with stasis and extra-vascular intraconjunctive hemorrhages. In the 8-Hz group, moderate edema was present near the optical nerve, and the 16-Hz group exhibited perineural hemorrhages in the optical nerve. *Day 7:* in both groups, conjunctiva blood vessels had expanded and arteries in the oculus fundus were narrower and twisted. Eyelid edema of the derma was identified in both groups. The most pronounced vascular changes were found in the eyelid conjunctiva: stasis, edema, and pericapillary hemorrhages. Sclera capillaries were overfilled with blood and extra-vascular hemorrhages were observed. *Day 15:* in both groups, conjunctiva vessels were narrower and twisted, and ocular globe conjunctiva exhibited nonvascularized

areas. Vascular changes as seen previously were more expressed: edema, paresis . state in capillaries (erythrocyte stasis), and extra-vascular erythrocytes. The iris exhibited narrower vessels. *Day 30:* narrowed and twisted vessels were clinically detected, with ocular fundus arteries and veins significantly narrowed and twisted, more pronounced in the 16-Hz group. In the eyelid conjunctiva, derma exhibited the same vascular changes seen before: edema and erythrocyte stasis. Sclera arteries and veins were larger, overfilled with blood, and with the presence of extra-vascular focal and diffuse hemorrhages with conjunctiva involvement. At all time points, the 16-Hz group disclosed more destruction than the 8-Hz group. *Day 60 (30 days post-exposure)*: clinical evaluations revealed less twisted and narrow arteries and veins, but morphological recovery was slower. In the 8-Hz group, moderate regeneration was observed in the eyelid conjunctiva epithelium. In the 16-Hz group, predominant retinal damage persisted. *Day 90:* no clinical changes were observed in either group [14].

Within an occupational setting (reinforced concrete factory), vessel changes in the palpebral and bulbar conjunctiva, and in the retina, were investigated among 214 workers (age range: 20–58 years), with 1–30 years of employment. Workers were divided into two groups:

- *Control group* (n = 54): not occupationally exposed to significant levels of infrasonic and lower frequency airborne pressure waves.

- *Exposed group* (n = 160): tonal 8 and 16 Hz at 96–100 dB, simultaneously with non-tonal 20–500 Hz at 91–93 dBA.

The exposed group was divided into subgroups as per years of professional activity. **Table 1** describes each subgroup and the vessel abnormalities found. No such abnormalities were found in the control population [14].

Within a different occupational setting (aircraft industry), ocular changes were studied in 23 male workers (average age: 42, range: 32–58 years). Lesions

Occupational exposure time	**1–2 yrs**	**3–10 yrs**	**11–20 yrs**	**20–30 yrs**
Number of workers	21	84	36	19
Palpebral and bulbar arteries (%)				
Enlarged	0	82	8	0
Narrow	0	17	91	100
Twisted	0	80	100	100
Retinal arteries (%)				
Enlarged	0	0	0	0
Narrow	0	91	100	100
Twisted	0	90	100	100
Retinal veins (%)				
Enlarged	0	87	11	0
Narrow	0	13	88	100
Twisted	0	75	97	100

Table 1.
Percentage of abnormal vessel changes seen in the palpebral and bulbar conjunctiva and retina among occupationally exposed workers [14].

were observed in the blood-retinal barrier in 19 workers (lesion types: 13 inactive, 2 active, 4 mixed). Choroidal circulation was altered in 14 workers (late perfusion with chronic features). Changes in retinal circulation were observed in four workers (type: 1 occlusive, 1 exudative, 2 mixed). Three workers presented with optic neuropathy (1 papillitis, 2 optic atrophy), and one exhibited sensorial retinal macular detachment [15]. The immediate effects of tonal exposures with 8 Hz at 130 dB, 2 hours daily, for 1, 7, 14 and 21 days, also revealed a breakdown of the blood-retinal barrier in the rat eye [16].

These studies strongly suggest that under the impact of infrasonic and lower frequency airborne pressure waves, a vascular response is mounted by ocular structures and could be related to decreased visual acuity in workers. Data in **Table 1** seem to indicate that, as exposure time progressed, vessels that were initially enlarged ceased to exist, apparently being replaced with narrower and twisted vessels. Enlarged vessels usually suggest the need for an increased blood supply. However, given the sustained mechanical insult, making the vessels narrower and twisting them throughout the structures may, in fact, reflect a more efficient blood delivery system.

This concept is further reinforced by the observation of narrow and twisted blood vessels in the gastric mucosa of rats, exposed to non-tonal, occupationally simulated (aircraft industry) acoustic environments characterized as 6.3–25 Hz at 70–90 dB and 40–500 Hz at 90–100 dB. Continuous exposure was applied, and evaluations occurred at 1, 3, 5, 9, and 13 weeks. In *3–5 weeks*, the gastric submucosal layer exhibited significantly increased thickness, when compared to non-exposed controls. This increased thickness was due to the proliferation of type IV collagen. Arterial walls disclosed significant intima and media thickening, ruptured internal elastic lamina, and thrombotic changes. In *9–13 weeks,* neoangiogenesis was observed, with the appearance of tortuous and twisted vessels. The authors concluded that, in the stomach, continuous exposure induced fibrosis that could be linked with neoangiogenesis, since collagen type IV is also an early marker of neoangiogenesis [17]. One of the earliest studies investigating the long-term effects of airborne pressure waves on gastric complaints was conducted in 1968, in a residential setting where changes in gastric function were associated with aircraft noise [18]. Within occupational settings, an increase in gastric complaints was documented among boiler-plant workers, 2 years after the implementation of mandatory hearing protection devices [19]. Among aircraft industry workers, gastrointestinal problems were among the earliest to appear after 1–4 years of professional activity [20].

Vascular changes were also identified in the liver structures of animals exposed to 2, 4, 8, or 16 Hz, at 90–140 dB, 3 hours daily, for 5–40 days. Exposures to 2 or 4 Hz induced less damage than exposures to 8 and 16 Hz. *Single, 3-hour exposures:* with 2 or 4 Hz and 90 dB, no changes were observed in the hepatic structures, while at 100–110 dB, liver parenchyma disclosed single fine hemorrhages. At 120 dB, increased arterial wall diameters were observed, as well as capillary lumen expansion, indicating the development of ischemia. At 130–140 dB, the number of hemorrhagic events increased, as did the number of affected hepatocytes. With 8 or 16 Hz exposures, damaged hepatocytes were present in the ischemic and non-ischemic areas. *Days 5–15:* more pronounced hepatocyte changes were seen. *Days 25–40*: a gradual death of changed hepatocytes was observed [21].

Hemorrhagic events in the lung were documented as early as 1969, within the Soviet and US space exploration studies, in dogs exposed to occupationally simulated (spaceflight) wide-band frequency range at 105–155 dB, for 1.5 or 2 hours. Hemorrhages up to 3 mm in diameter were observed beneath the pleura. As exposure time and decibel level increased, the number of hemorrhages increased but never

exceeded 3 mm in diameter. Microscopic analyses of the hemorrhagic sections disclosed ruptured capillaries and larger blood vessels [22]. In a laboratory setting, rats received tonal exposures to 2, 4, 8, or 16 Hz at 90–140 dB, 3 hours daily, for 40 days. Analysis time points were conducted after 3 hours, at 5, 10, 15, 24, and 40 days of exposure, as well as during post-exposure times. *Single, 3-hour exposures:* with 2 or 4 Hz at 90–110 dB, mosaic hemorrhages were observed under the pleura, covering the entire lung surface. With 8 Hz at 110 dB, more hemorrhagic expression was observed. With 8 or 16 Hz at 120–140 dB, larger hemorrhagic foci were disclosed. Within the alveolar capillary network and postcapillary venules, vessel diameters were increased with 2 or 4 Hz at 90–110 dB, leading to large hemorrhages and perivascular edema. Erythrocyte overflow in alveolar capillaries was observed with 8 or 16 Hz at 110 dB. With 8 or 16 Hz at 120 or 140 dB, lung tissue exhibited large hemorrhagic foci in the connective tissue septa of the bronchi-pulmonary segments. In all exposure types, capillary changes were followed by alveolar epithelium desquamation and basal membrane denudation. *Longer exposures:* with 8 Hz at 120 dB, acinuses became filled with erythrocytes, and interstitial hemorrhagic foci caused a strong deformation of the respiratory bronchioles. With 8 or 16 Hz at 140 dB, ruptured vascular walls were observed leading to decreased alveolar lumen [23].

The highly invasive bronchoscopic evaluation with biopsy was performed among a group of volunteer subjects, with occupational or residential exposures to infrasonic and lower frequency airborne pressure waves, as detailed in **Table 2**.

Bronchoscopic observations in all patients revealed small submucosal, vascular-like lesions ("pink" lesions), located distally in both tracheal and bronchial trees, and uniformly distributed bilaterally near the spurs. Biopsies were performed on the abnormal mucosa (pink lesions) and on the apparently normal mucosa (outside of the pink lesions). In the non-pink areas, some vessel wall thickening was visible. In the pink areas, the basal membrane disclosed abnormal neovascularization, with thickened blood vessel walls and scarce lumen. No gender differences were identified [24].

4.2 Collagen and connective tissue

Collagen, composed of triple-helix tropocollagen chains, is the most abundant protein in the human body, a key component of the fasciae, and is produced by fibroblast cells. It has long since been considered as the "steel" of the human body [25], but its energy storage capacity has been shown to be 10 orders higher than in spring steel [26]. Different types of collagen have different mechanical properties. Type IV collagen (increased in the exposed gastric mucosa [17]—see above), is organized into X-shaped structures and is commonly found in the basal membrane of arterial walls, hence its increased expression during angiogenesis.

In *day 5* of the eyelid-and-bulbar-conjunctiva animal studies (see above [13]), collagen fibers in the connective tissue were enlarged, as were some fibroblast nuclei; on *day 10*, adipose cells in the connective tissue had been redistributed and positioned in the vascular areas of the conjunctiva. In the second animal study described above [14], *day 3* included edema of the sclera causing separation of collagen filaments in the 16 Hz group, and by *day 7,* this was observed in the 8-Hz group as well; *day 15:* focal and disseminated disorganization of sclera collagen fibers was observed in both groups; *day 30:* homogenization and disorganization of collagen in the derma while, in the sclera, collagen fibers were persistently separated due to edema, with some undergoing dystrophic and necrotic changes. Slow regeneration was observed during the post-exposure periods.

In the lungs of dogs studied within the scope of space exploration (see above [22]), focal enlargement of the alveoli involved the stretching of connective tissue

Profession/type of exposure	Gender	Age	Smoking
Aircraft technician	Male	48	Mild
Aircraft technician	Male	52	No
Aircraft technician	Male	59	Mild
Combat pilot	Male	61	No
Helicopter pilot	Male	59	Moderate
Aircraft pilot	Male	54	No
Merchant marine	Male	37	No
Military helicopter nurse	Female	56	No
Flight attendant	Female	36	No
Flight attendant	Female	39	No
Flight attendant	Female	40	No
Homemaker	Female	54	Mild
Homemaker	Female	59	No

Table 2.
Description of subjects who received bronchoscopic evaluations with biopsy [24].

structures of alveoli walls. In the biopsy images of the bronchoscopic study (see above [24]), non-pink areas disclosed a thickened basement membrane with abnormal amounts of collagen, while the pink areas disclosed an even thicker membrane with very large amounts of collagen. The abnormal neovascularization was embedded within collagen bundles. Retraction of structures neighboring the collagen fibers was not observed. A marked reinforcement of the cytoskeleton and intercellular junctions was seen in the pink areas, as compared to non-pink areas. The five individuals that disclosed images of collagen fiber degeneration and disruption also tested positive for antinuclear antibodies.

Under an occupationally simulated acoustic environment, characterized as 20–200 Hz at 70–90 dB (aircraft industry), and occupationally simulated exposure schedules (8 hours daily, 5 days weekly, weekends in silence), focal interstitial fibrosis was found in the lung parenchyma of rats after a cumulative 4000-hour exposure. Additionally, thickened alveoli walls and dilated alveoli were observed [27]. Tracheal epithelium in similarly exposed rats disclosed significant subepithelial fibrosis [28, 29], and with longer occupationally simulated exposures, the subepithelial layer became composed of hyperplastic collagen bundles, some with a degenerative pattern. Cellular edema was also observed [28, 30].

Within an occupational setting (aircraft industry) and investigating long-term outcomes, high-resolution CT scans of the lungs and respiratory function tests were provided to 21 nonsmoker male workers, who were divided into two groups: with (n = 7, average age: 42) and without (n = 15, average age: 36) complaints of airflow limitations. There was a significant relationship between the presence of symptoms and images of lung fibrosis through the CT scan. No differences existed among the groups when comparing the percentage of predicted values of lung function [31].

Fasciae abnormalities have been most prominently studied in the pericardia of exposed workers, subsequent to autopsy findings in an aircraft industry worker that disclosed a grossly thickened pericardium [32]. Pericardial morphological changes were studied among 12 male workers: three aircraft technicians, four fixed-wing aircraft pilots, four helicopter pilots, and one long-haul truck driver. Pericardial samples were removed with informed consent of the patient and Ethics Committee

approval, at the beginning of cardiac surgery (prescribed for other reasons by the National Healthcare Service). In all cases, there were no visual adherences, or inflammatory aspects and pericardia were grossly thickened. The classical, three pericardial layers were identified: serosa, fibrosa, and epipericardium. However, in all cases, the fibrosa had split in two and, in between, a new layer of loose tissue was observed, consisting of vessels, nerves, arteries, and lymphatics surrounded by adipose tissue. Both fibrosa layers were composed almost entirely by wavy, interwoven collagen bundles, surrounded by numerous cytoplasmic extensions (whose mother cell was difficult to identify), and interspersed with some elastic fibers. The new, loose tissue layer sandwiched in between the split fibrosa contained blood and lymphatic vessels, adipose tissue, and nerves. Both the loose tissue layer and the fibrosa layers contained macrophages and vascular hyperplasia, also seen in lymphatic vessels [33–36]. Pericardial and cardiac valve thickening has also been confirmed through echocardiography studies in occupational settings (aircraft [37] and commercial-airline industries [38]), with thickness increasing with increasing exposure time. In residential settings, pericardial and valve thickening [39] and increased arterial stiffness [40] were observed in populations chronically exposed to military-training exercises [39], and transportation systems [40].

4.3 Heart cells and tissues

In 1983, electron microscopy techniques were used to study animal myocardia exposed to single and multiple infrasonic exposures of 4–16 Hz at 90–150 dB, 3 hours daily, for 45 days, and post-exposure time points were included. No changes were observed with single exposures at 4–6 Hz and at less than 100 dB, when compared to non-exposed controls. *Single exposure with 4–10 Hz at 120–125 dB:* induced decreased arterial diameter and capillary expansion, with resulting focal ischemia. Images of intracellular myocytolysis were frequently found. These processes were reversible. *Multiple exposures with 4–10 Hz at 120–125 dB for 5–25 days*: ventricle fibrillation and subsegmental contractures in ischemic foci were identified. Myofibril fragmentation was observed in the Z-line, sarcoplasmic reticulum structures were absent, cell nuclei were deformed, and chromatin was found accumulated under the nuclear membrane. *post-exposure*: intracellular regeneration was concomitant with damaged cells. In surviving cells, mitochondria were increased in number and size, and both myofilaments and sarcoplasmic reticulum elements were being created. Intracellular regeneration was slow and ended with the creation of Z-lines, after which myofibrils became normal and myocardiocytes completely recovered. *Single exposure with 10–15 Hz at 135–145 dB:* more pronounced myocardial damage, with partial death of myocardiocytes, resulting in myocardiocyte dystrophy. Damaged cells included chromatin condensation and redistribution to the nuclei membrane. Less damaged cells regenerated after 5–10 days post-exposure. *Multiple exposures with 10–15 Hz at 135–145 dB:* persistent myocardial ischemia related to vascular changes and accompanied by cardiocyte damage. After 15–25 days post-exposure, recovered cells began functioning normally despite the presence of abnormal structures within the cellular cytoplasm, namely, giant mitochondria [41].

Cardiac injury was studied in rat cardiomyocytes exposed to tonal 5 Hz at 130 dB, 2 hours daily, for 1, 7, or 14 days. *Days 1–7:* SERCA2 (sarcoplasmic reticulum Ca^{2+} ATPase 2, an enzyme with calcium-transporting properties and involved in the decomposition of ATP into ADP) was significantly increased, and swollen mitochondria were observed in the cardiomyocytes. *Day 7:* SERCA2 was significantly decreased and an increased number of swollen mitochondria were observed. *Day 14:* SERCA2 was significantly decreased and platelet aggregation was found in the intercellular substance. Intercellular calcium ion (Ca^{2+}) concentration significantly

increased with increasing exposure time [42]. With similar exposure protocols, another study repeated the SERCA2 and intercellular Ca^{2+} concentrations, but also included evaluations of the expression of whole cell L-type Ca^{2+} currents (WLCC) and the mRNA expression of a subunit of the L-type Ca^{2+} channel (LCC). SERCA2 and intercellular Ca^{2+} concentrations behaved as described immediately above, while the expression of WLCC and mRNA expression of LCC increased with increasing exposure time [43].

For three continuous months, rats were exposed to non-tonal, occupationally simulated (aircraft industry) acoustical environments characterized as 6.3–25 Hz at 70–90 dB and 40–500 Hz at 90–100 dB. Ventricular cardiac muscle and interstitial fibrosis were quantified and compared to non-exposed controls. Exposed rats disclosed a 97.5% increase in fibrosis in the left ventricle, an 81.5% increase in the interventricular septum, and an 83.7% increase in the right ventricle. No significant differences were found in the mean values of cardiac muscle in the left and right ventricles, when compared to non-exposed controls. However, the fibrosis-to-muscle ratio was significantly higher in the exposed rats, indicating significant ventricular myocardial fibrosis [44].

In another study, rats were exposed to a non-tonal, occupationally simulated (textile mill) environment rich in infrasonic and lower frequency components, under an occupationally simulated schedule (8 hours daily, 5 days weekly, weekends in silence), for 1, 3, 5, and 7 months. Ventricular coronary artery caliber, artery wall thickness, and size of arterial perivascular tissue were quantified in a total of 130 arteries (61 exposed and 69 controls). No changes were observed in arterial lumen caliber, and in arterial wall thickness, when compared to non-exposed controls. Perivascular tissue was more prominent in the exposed samples and seemed to exhibit fibrotic development. Lumen-to-wall ratio showed no differences, while wall-to-perivascular-tissue ratio showed a significant increase, as compared to non-exposed controls [45].

In animals exposed to 2–20 Hz peaking at 114 dB, for 28 continuous days, ventricular arteries were studied as to the dimensions of lumen, wall, and perivascular space. An additional group of animals received the same exposure but were treated with dexamethasone (a corticosteroid). Blind evaluation of 31 arteries disclosed increased perivascular spaces in the exposed groups, reflected in the significantly reduced wall-to-perivascular-space ratio, as compared to non-exposed controls. No changes were observed in the lumen-to-wall ratio. With dexamethasone treatment and exposure, no differences were observed in the wall-to-perivascular-space ratio, as compared to controls, suggesting an underlying inflammatory mechanism [46].

Gap junctions are a fundamental component of intercellular communication, allowing inorganic ions and small water-soluble molecules to pass directly from one cell's cytoplasm to another. Gap junctions are formed by protein complexes (connexons) each composed of six subunits made of the protein connexin. Cardiac connexin43 (Cx43) is a component of gap junctions, and its reduction in combination with increased collagen deposition and interstitial fibrosis has been associated with ventricular arrhythmias [47]. Within this context, rats were exposed to non-tonal, occupationally simulated (aircraft industry) acoustical environments characterized by 6.3–25 Hz at 70–90 dB and 40–500 Hz at 90–100 dB, for three continuous months. Immunohistochemical quantification of Cx43 was conducted on the left ventricle, interventricular septum, and right ventricle. Significantly decreased Cx43-to-muscle ratios were found in the exposed rats, as compared to non-exposed controls, suggesting the possibility of arrhythmogenic consequences [48].

4.4 The hippocampus

Prior studies have shown that the hippocampus is involved in learning and memory impairment, such as that seen in rodents after infrasound exposure [49]. The hippocampus—located between the cerebral hemispheres and the brainstem—was classically considered as part of the limbic system. The hippocampus proper is divided into four regions (CA1, CA2, CA3, and CA4), each with different input and output pathways. The Dentate Gyrus (DG) is an additional hippocampus structure and that contributes to the formation of new episodic memories, and spontaneous exploration of novel environments. In the central nervous system (CNS), neuroglia consists of the non-neuronal cells (oligodendrocytes, astrocytes, ependymal cells, and microglia) and is often referred to as the connective tissue of the brain. Glial cells surround neurons to hold them in place, supply them with oxygen and nutrients, insulate them from one another, destroy pathogens, and remove dead neurons.

Glial fibrillary acidic protein (GFAP) is an intermediate filament protein expressed by numerous cells within the CNS, and although its exact function remains unknown, it appears to be involved in maintaining the mechanical strength of astrocytes. The expression of GFAP was studied in the brains of mice exposed to 16 Hz at 130 dB, 2 hours daily, for 1, 7, 14 21, or 28 days. GFAP expression was increased in the hippocampus, cortex, and hypothalamus in a time-dependent manner [50].

Corticotrophin releasing hormone (CHR) is a peptide hormone involved in the stimulation of the pituitary synthesis of ACTH (adrenocorticotropic hormone) as part of the hypothalamic-pituitary-adrenal axis' response to stress. Corticotrophin releasing hormone-receptor 1 (CHR-R1) has wide expression in the CNS. It plays important roles in fear learning and consolidation in the amygdala, in stress-related modulation of memory function in the hippocampus, and in arousal regulation in the brainstem. Prior studies showed that infrasound exposures caused an upregulation of CRH and CRH-R1 in neurons of the hypothalamic paraventricular nucleus [51]. Recent studies have also shown that CRH is expressed in activated microglial cells [52]. Within this context, rats and *in vitro* cultured microglial cells were exposed to 16 Hz at 130 dB for 2 hours, after which changes in CHR-R1 were examined. *In vivo* exposure disclosed activation of microglial cells and an upregulation in the expression of CRH-R1 in the hypothalamic periventricular nucleus. *In vitro* exposure disclosed that, in the absence of neurons, microglial cells were activated and CRH-R1 expression was upregulated. These data suggest that both neurons in the hypothalamic periventricular nucleus and microglial cells are effector cells for infrasound-elicited responses [51].

The transient receptor potential cation channel, subfamily V, member 4 (TRPV4) protein acts as a calcium channel that is also mechanosensitive. It plays important roles in the systemic regulation of osmotic pressure by the brain, in skeletal growth and structural integrity, in airway and lung function, retinal and inner ear function, and in pain. Animals were exposed to 8 or 16 Hz at 90, 100 or 130 dB, 2 hours daily, for 14 days. Rat learning and memory abilities were most severely impaired with 16 Hz at 130 dB at days 7 and 14, with prominent loss of hippocampal CA1 neurons, as compared to non-exposed controls. Significant astrocyte and microglial activation was seen in the hippocampus after days 1 and 7, and before neuronal apoptosis became evident. *In vivo* pharmacological intervention causing the inhibition of glial activation protected against neuronal apoptosis. *In vitro*, exposed glial cells released proinflammatory cytokines, a key factor for neuronal apoptosis. In both *in vivo* and *in vitro*, expression levels of

TRPV4 were increased as compared to non-exposed controls. Pharmacological or knock-out intervention of TRPV4 in cultured glial cells decreased the levels of inflammatory cytokines and attenuated neuronal apoptosis. This study also demonstrated the involvement of calmodulin and protein kinase C signaling pathways in the response to infrasonic exposures. These data suggest that TRPV4 expressed by glial cells is potentially a key factor in infrasound-induced neuronal impairment [53].

Neonatal rat hippocampal astrocyte cultures were exposed to 16 Hz at 130 dB for 15, 30, 60, 90, 120, and 240 minutes. Extra-cellular glutamate levels increased with increasing exposure time, and at 90 min, there was a 100% increase over baseline. The astroglial expression of Cx43 (connexin43—see above) was increased, as compared to non-exposed controls, as was the synthesis of Cx43 mRNA. Through additional evaluations using pharmacological and knock-out interventions, the authors concluded that infrasonic exposures induced astrocytes to release glutamate, and that Cx43 gap junctions were required for the exposure-induced glutamate release [54].

The endocannabinoid system includes lipid-based retrograde neurotransmitters, expressed throughout the CNS, and involved in fertility, pregnancy, pre-and postnatal development, appetite, pain-sensation, mood, and memory. Animals were exposed to 16 Hz at 130 dB, 2 hours daily, for 14 days. Cannabinoid (CB) receptors 1 and 2 in the CA1 hippocampal region of the exposed rats were downregulated in a time-dependent manner, as compared to non-exposed controls. Apoptotic cells in the CA1 only became obvious after day 5, and cell death coincided with the decreased expression of CB receptors. Through pharmacological intervention, activation of CB receptors significantly reduced the number of apoptotic cells, ameliorated the behavior performance of exposed rats, and reduced the infrasound-elevated levels of proinflammatory cytokines. These data suggest that CB receptors could potentially serve as promising targets for future treatments against infrasound-induced injury [55].

Fibroblasts synthesize extracellular matrix (glycosaminoglycans, reticular, and elastic fibers) and collagen, and, in addition to their structural role, fibroblasts are also important for mounting the immune response to tissue damage. Fibroblast growth factors (FGF) signal through fibroblast growth factor receptors (FGFR). The fibroblast growth factor 2/fibroblast growth factor receptor 1 (FGF2/FGFR1) signaling pathway was investigated in animals and in cultured astrocytes, exposed to 16 Hz at 150 dB, 2 hours daily, for 1, 3, or 7 days. In both experimental models, astrocyte activation increased with exposure time and astrocyte-expressed FGFR1 was downregulated as compared to non-exposed controls. Pharmacological intervention using FGF2 exerted an inhibitory effect on infrasound-induced astrocyte activation, inhibited the elevation of proinflammatory cytokines, upregulated the expression of FGFR1, and alleviated neuron loss in CA1 hippocampus region. Inhibition of the FGF2/FGFR1 pathway aggravated astrocyte-mediated inflammation after infrasonic exposure. The authors concluded that astrocyte-mediated inflammation was involved in infrasound-induced neuronal damage and that the FGF2/FGFR1 pathway played a key role [56].

In a laboratory setting, rats were exposed to tonal 8 Hz at 140 dB, 2 hours daily, for 3 days. A post-exposure, 1-week time point was also established. Significant damage of hippocampus morphology was observed in exposed rats, and recovery was seen after 1 week of post-exposure. Neuronal apoptosis was significantly increased after 24- and 48-hour exposures, as compared to non-exposed controls, and then decreased after 1 week post-exposure. Expression of heat shock protein 70 (HSP70) peaked at 24 hours and was decreased at 48 hours [57].

5. Conclusions

Exposure to infrasonic and lower frequency airborne pressure waves can cause cellular and tissue damage depending on frequency, dB-level, and exposure time, while the viscoelastic properties inherent to biological tissues impart a nonlinear response to this type of acoustic stressor. The complex mechanosensitive and biochemical cellular signaling pathways mediating this cellular damage have not yet been pinpointed, although fasciae structures and connective tissues (including the neuroglia) seem to be the most sensitive under longer term exposures. Immediate exposures appear to induce inflammatory processes that do not seem to be maintained with longer exposures.

Widespread vascular involvement (not limited to the biological structures addressed herein) was observed in palpebral and bulbar conjunctiva and retina, gastric mucosa, liver structures, lungs, pleura and tracheae, alveoli, pericardia, and coronary arteries. This vascular response may (unsuspectingly) be the underlying cause of many symptomatic complaints. Cognitive deficits oftentimes documented within residential field laboratories may not merely be due to sleep deprivation, but also to hippocampal neuronal damage. Fasciae morphogenesis speaks to the demand on the whole-body structural integrity elicited by this type of external mechanical insult, while collagenous growths and hemorrhagic events of a focal nature may reflect concomitant resonance phenomena.

Recovery periods are not linear, and 2-hour daily exposures imply a 22-hour nonexposure period. This presents a problem for continuous exposures, such as those encountered in some professional activities and most residential environments. The underlying objectives of most of the studies discussed herein are related to occupational exposures and do not consider continuous exposures at less than 90 dB, nor are pressure pulsed trains presented within the laboratorial acoustic environments. In residential environments, however, these attributes are often present. The simulation of residential exposures does not appear to have yet been integrated into laboratory settings and protocols.

The whole-body response also elicits the immune system, affects organs of the reproductive system, changes receptor cells in the vestibular semicanals and auditory cochlea, and induces genotoxic effects, including teratogenesis. This is a pioneering field of science, still in its infancy and urgently requiring scientists from multidisciplinary areas of study because, ultimately, the health of human populations and their offspring must be protected.

Conflict of interest

None.

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