Property Owner	SBL #	Mailing Address
Roy and Winifred Bish	46.-2-41	3073 Seneca Tpk. W. Canastota, NY 13032
Michael and Tammy Evans	46.-2-43.1	1078 Sugar Maple Dr. Oneida, NY 13421
Ronald Holmes	46.-2-47.811	1222 Crescent Ave. Oneida, NY 13421
Jeffrey and Deborah Socha	46.-2-47.51	6107 Forest Ave. Oneida, NY 13421
Hugh and Betty Sue Wilke	54.-1-4	4911 Burleson Rd. Oneida, NY 13421
Randy Lopitz	54.-1-1.6	4943 Forest Ave. Oneida, NY 13421
Richard and Sharon Lopitz	54.-1-1.1	4927 Forest Ave. Oneida, NY 13421
Gail Hood	46.-2-42.41	1613 Brewer Rd. Oneida, NY 13421
Gregory and Pamela Noll	46.-2-42.22	1439 Brewer Rd. Oneida, NY 13421
Albino and Rose Ballini	46.-2-42.23	1423 Brewer Rd. Oneida, NY 13421

March 20, 2023

From: David Strong
Project Developer
New Leaf Energy

To: Neighbor of Forest Ave Community Wind Project

Dear Neighbor:

New Leaf Energy is preparing to submit an application to the City of Oneida for a Community Wind project located at 4949 Forest Ave, on parcel 46-2-42.3. As part of this application, we will be requesting a variance from the height requirements of the local wind turbine ordinance. Modern turbines spin slowly, are more efficient and taller than older turbines. This requires a maximum tip height of 560’ rather than the 450’ height specified in the City of Oneida bylaw. We would like to ask for your feedback filling out the enclosed form and returning it using the prepaid envelope included. We believe that this project will provide significant benefits to the community and we would greatly appreciate your support of the project. Please see below for more information.

What is Community Wind?

Most importantly, it’s NOT a utility-scale wind farm. The proposed project uses minimal acreage and includes only 1 wind turbine. It will generate locally-sourced clean energy that stays in your community to power local homes and businesses.

Benefits for your Community

Community Host Agreement

New Leaf Energy intends to enter into an agreement with the City of Oneida that provides funding to the city as the host community. These funds can be used for local infrastructure, schools, or other projects that benefit the community.

Local tax revenue

Municipal services including the city, county, and school districts all benefit from the increased tax revenue from the project, all of which is negotiated as part of the permitting process.

Local jobs

Projects like this typically create 30-40 jobs over the life of the system, including some long-term jobs for operations & maintenance as well as short-term construction jobs.

Energy freedom

Once the project is operational, community members can choose to buy their electricity directly from the program — keeping the clean energy in your community.

Affordable electricity

Wind energy is the most affordable way to generate electricity today.

Reduced emissions

Projects like this one enable the state to reach its goals for 70% renewable energy generation by 2030 and zero-emissions electricity by 2040.

Property values

Long-term studies show that wind power does not impact property values. In fact, it drives economic development and services that directly benefit the host communities.

Thank you for your time. If you have any questions regarding the above, please do not hesitate to call.

Sincerely,

New Leaf Energy, Inc.

David Strong
Project Developer
dstrong@newleafenergy.com
Ph: (518) 217-8342

FedEx Shipment Receipt

Address Information

Ship to:	Ship from:
Albino N. Ballini and Rose T. Balli	Samuel Wood
	New Leaf Energy, Inc.
1423 Brewer Road	22 Century Hill Drive
	Suite 303
ONEIDA, NY	LATHAM, NY
13421	12110
US	US
518-618-1375	5186181375

Shipment Information:
Tracking no.: 771652637661
Ship date: 03/24/2023
Estimated shipping charges: 28.54 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services: Residential Delivery
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

Thank you for shipping online with FedEx ShipManager at fedex.com.

Please Note

FedEx will not be responsible for any claim in excess of $100 per package, whether the result of loss, damage, delay, non-delivery, misdelivery, or misinformation, unless you declare a higher value, pay an additional charge, document your actual loss and file a timely claim. Limitations found in the current FedEx Service Guide apply. Your right to recover from FedEx for any loss, including intrinsic value of the package, loss of sales, income interest, profit, attorney's fees, costs, and other forms of damage whether direct, incidental, consequential, or special is limited to the greater of $100 or the authorized declared value. Recovery cannot exceed actual documented loss. Maximum for items of extraordinary value is $1000, e.g., jewelry, precious metals, negotiable instruments and other items listed in our Service Guide. Written claims must be filed within strict time limits; Consult the applicable FedEx Service Guide for details.
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Shipment Receipt

Address Information

Ship to:	**Ship from:**
Gail S. Hood	Samuel Wood
	New Leaf Energy, Inc.
1613 Brewer Road	22 Century Hill Drive
	Suite 303
ONEIDA, NY	LATHAM, NY
13421	12110
US	US
518-618-1375	5186181375

Shipment Information:

Tracking no.: 771652576839
Ship date: 03/24/2023
Estimated shipping charges: 28.54 USD

Package Information

Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services: Residential Delivery
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:

Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

Thank you for shipping online with FedEx ShipManager at fedex.com.

Please Note

Shipment Receipt

Address Information

Ship to:	Ship from:
Gregory J. Noll and Pamela S. Noll	Samuel Wood
	New Leaf Energy, Inc.
1439 Brewer Road	22 Century Hill Drive
	Suite 303
ONEIDA, NY	LATHAM, NY
13421	12110
US	US
518-618-1375	5186181375

Shipment Information:
Tracking no.: 771652601330
Ship date: 03/24/2023
Estimated shipping charges: 28.54 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services: Residential Delivery
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

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Shipment Receipt

Address Information

Ship to:	Ship from:
Jeffrey L. Socha and Deborah M. Soc	Samuel Wood
	New Leaf Energy, Inc.
6107 Forest Ave	22 Century Hill Drive
	Suite 303
ONEIDA, NY	LATHAM, NY
13421	12110
US	US
518-618-1375	5186181375

Shipment Information:
Tracking no.: 771652454588
Ship date: 03/24/2023
Estimated shipping charges: 28.54 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services: Residential Delivery
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

Please Note

Shipment Receipt

Address Information

Ship to:	Ship from:
Michael Patrick Evans and Tammy Ann	Samuel Wood
	New Leaf Energy, Inc.
1078 Sugar Maple Drive	22 Century Hill Drive
	Suite 303
ONEIDA, NY	LATHAM, NY
13421	12110
US	US
518-618-1375	5186181375

Shipment Information:
Tracking no.: 771652386569
Ship date: 03/24/2023
Estimated shipping charges: 28.54 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services: Residential Delivery
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

Thank you for shipping online with FedEx ShipManager at fedex.com.

Shipment Receipt

Address Information

Ship to:	**Ship from:**
Niagara Mohawk DBA National Grid	Samuel Wood
	New Leaf Energy, Inc.
300 Erie Blvd West	22 Century Hill Drive
Building D-G	Suite 303
SYRACUSE, NY	LATHAM, NY
13202	12110
US	US
518-618-1375	5186181375

Shipment Information:
Tracking no.: 771652716861
Ship date: 03/24/2023
Estimated shipping charges: 23.11 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services:
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

Thank you for shipping online with FedEx ShipManager at fedex.com.

Please Note

Shipment Receipt

Address Information

Ship to:	Ship from:
Randy A. Lopitz	Samuel Wood
	New Leaf Energy, Inc.
4943 Forest Ave	22 Century Hill Drive
	Suite 303
ONEIDA, NY	LATHAM, NY
13421	12110
US	US
518-618-1375	5186181375

Shipment Information:
Tracking no.: 771652521214
Ship date: 03/24/2023
Estimated shipping charges: 28.54 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services: Residential Delivery
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

Please Note

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Shipment Receipt

Address Information

Ship to:	**Ship from:**
Richard L. Lopitz and Sharon Lopitz	Samuel Wood
	New Leaf Energy, Inc.
4927 Forest Ave	22 Century Hill Drive
	Suite 303
ONEIDA, NY	LATHAM, NY
13421	12110
US	US
518-618-1375	5186181375

Shipment Information:
Tracking no.: 771652544958
Ship date: 03/24/2023
Estimated shipping charges: 28.54 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services: Residential Delivery
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

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Shipment Receipt

Address Information

Ship to:	Ship from:
Rondal E. Holmes	Samuel Wood
	New Leaf Energy, Inc.
1222 Crescent Ave.	22 Century Hill Drive
	Suite 303
ONEIDA, NY	LATHAM, NY
13421	12110
US	US
518-618-1375	5186181375

Shipment Information:
Tracking no.: 771652426739
Ship date: 03/24/2023
Estimated shipping charges: 28.54 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services: Residential Delivery
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

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Shipment Receipt

Address Information

Ship to:
Roy E. Bish and Winifred R. Bish

3073 Seneca Tpke West

CANASTOTA, NY
13032
US
518-618-1375

Ship from:
Samuel Wood
New Leaf Energy, Inc.
22 Century Hill Drive
Suite 303
LATHAM, NY
12110
US
5186181375

Shipment Information:
Tracking no.: 771652321149
Ship date: 03/24/2023
Estimated shipping charges: 33.73 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services: Residential Delivery
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

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FedEx Shipment Receipt

Address Information

Ship to:	Ship from:
USA in Trust For The Oneida Nation	Samuel Wood
	New Leaf Energy, Inc.
1849 C St NW	22 Century Hill Drive
	Suite 303
WASHINGTON, DC	LATHAM, NY
20240	12110
US	US
518-618-1375	5186181375

Shipment Information:
Tracking no.: 771652674997
Ship date: 03/24/2023
Estimated shipping charges: 23.11 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services:
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

Thank you for shipping online with FedEx ShipManager at fedex.com.

Please Note

Shipment Receipt

Address Information

Ship to:	**Ship from:**
Warren Broadcasting Co., Inc.	Samuel Wood
	New Leaf Energy, Inc.
4911 Burleson Road	22 Century Hill Drive
	Suite 303
ONEIDA, NY	LATHAM, NY
13421	12110
US	US
518-618-1375	5186181375

Shipment Information:
Tracking no.: 771652495316
Ship date: 03/24/2023
Estimated shipping charges: 23.11 USD

Package Information
Pricing option: FedEx Standard Rate
Service type: Priority Overnight
Package type: FedEx Envelope
Number of packages: 1
Total weight: 1 LBS
Declared Value: 0.00 USD
Special Services:
Pickup/Drop-off: Drop off package at FedEx location

Billing Information:
Bill transportation to: MyAccount-420
Your reference: 4949 Forest Ave Neighbor Sub
P.O. no.:
Invoice no.:
Department no.:

Thank you for shipping online with FedEx ShipManager at fedex.com.

Please Note

The form below has been submitted to all abutting property owners. Responses and/or proof of mailing will be provided to the City prior to a public hearing date.

Statement from Adjoining Property Owner

To be completed by the Petitioner

Owner:
Oneida Wind 1, LLC. c/o New Leaf Energy

Project address:
0 Brewer Road

Requested variance:
Construction of a 560-foot (total height) wind turbine rather than a 450-foot turbine allowed under the City Ordinances.

I certify that the plans presented to the undersigned neighbor for his/her review are identical to those plans for which an Area Variance is being requested. *

Brandon Smith, New Leaf Energy, Applicant 3/21/2023

Signature of Owner Date

To be completed by the Neighbor

Name: DR. MICHAEL EVANS

Address: 1078 SUGAR MAPLE DRIVE

I have reviewed the above request for an Area Variance.

☐ ~~I have no objection to the above request.~~
■ I object to the above request.

3-27-23

Signature Date

*Please Note: For ease of viewing, a single plan sheet has been included. PDF or paper copies of the full engineering plan set are available by contacting Brandon Smith at bsmith@newleafenergy.com or calling 978-221-3093

The form below has been submitted to all abutting property owners. Responses and/or proof of mailing will be provided to the City prior to a public hearing date.

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To be completed by the Petitioner

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Oneida Wind 1, LLC. c/o New Leaf Energy

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I certify that the plans presented to the undersigned neighbor for his/her review are identical to those plans for which an Area Variance is being requested. *

[signature] Brandon Smith, New Leaf Energy, Applicant — 3/21/2023

Signature of Owner — Date

To be completed by the Neighbor

Name: Winifred R. Roy E Bish

Address: 1323 Brewer Road Oneida N.Y.

I have reviewed the above request for an Area Variance.

- ☐ I have no objection to the above request.
- ☒ I object to the above request. times -2-

Winifred R. Bish — 9/5/2023

Signature — Date

Roy E Bish

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I certify that the plans presented to the undersigned neighbor for his/her review are identical to those plans for which an Area Variance is being requested. *

[signature] Brandon Smith, New Leaf Energy, Applicant 3/21/2023

Signature of Owner Date

To be completed by the Neighbor

Name: PAMELA SPADER Noll

Address: 1439 Brewer Rd. Oneida, NY 13421

I have reviewed the above request for an Area Variance.

- ☐ I have no objection to the above request.
- ☒ I object to the above request. !

[signature] 3/29/23

Signature Date

*Please Note: For ease of viewing, a single plan sheet has been included. PDF or paper copies of the full engineering plan set are available by contacting Brandon Smith at bsmith@newleafenergy.com or calling 978-221-3093

The form below has been submitted to all abutting property owners. Responses and/or proof of mailing will be provided to the City prior to a public hearing date.

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To be completed by the Petitioner

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0 Brewer Road

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I certify that the plans presented to the undersigned neighbor for his/her review are identical to those plans for which an Area Variance is being requested. *

[signature] Brandon Smith, New Leaf Energy, Applicant — 3/21/2023

Signature of Owner — Date

To be completed by the Neighbor

Name: Gail S. Hood

Address: 1613 Brewer Rd Oneida NY 13421

I have reviewed the above request for an Area Variance.

☐ I have no objection to the above request.
☒ I object to the above request.

Gail S. Hood — 3/27/23

Signature — Date

*Please Note: For ease of viewing, a single plan sheet has been included. PDF or paper copies of the full engineering plan set are available by contacting Brandon Smith at bsmith@newleafenergy.com or calling 978-221-3093

From: Mary Jo Donaldson
To: Christopher Henry
Subject: Re: Proposed wind turbine on Forest Ave/Brewer…
Date: Tuesday, March 28, 2023 10:35:13 AM

Mr. Henry,

Thank you for your reply. I would like to voice another big concern that we have regarding the proposed wind turbine.

After talking to several neighbors, it came to our attention that when a tower was built off Crescent Ave., Oneida N.Y., they blasted to get the tower installed. Several neighbors lost their only water supply, their wells.

Our property on Forest Ave. and all the land up here is all rock, barely under the surface. We have had to have two wells drilled, and the last time we were without water for over a month. They would hit water and stop for the day, come back the next day, and it had caved in. They needed to line our entire well to prevent the collapsing of the sides. This was a huge cost and we certainly would not want to be without water again, or incur the cost of drilling another well. Who would be responsible if we did lose our well water because of the construction of a wind turbine?

Sincerely,

John and Mary Jo Donaldson
4875 Forest Ave.
Oneida, NY
315-363-8728

Sent from my iPad

> On Mar 28, 2023, at 9:58 AM, Christopher Henry <chenry@oneidacityny.gov> wrote:
>
> Donaldson's,
>
> Thank you for your input, I will be sure to provide this information to the PCZBA as they make their determinations related to this project. It is anticipated that the PCZBA will hear a presentation on 4/11/23 at 6:00 pm in the Common Council Chambers. It is at this meeting, the PCZBA will schedule the date for the public hearing.
>
> Should you have any questions or any further questions or concerns, please do not hesitate to contact me.
>
> Best regards,
>
>
>
> Christopher Henry
> Director of Planning and Development
>
> City Phone: 315-363-4800 Direct Line 315-363-7467
> Web https://urldefense.proofpoint.com/v2/url?u=http-3A__www.oneidacity.com&d=DwIFaQ&c=euGZstcaTDllvimEN8b7jXrwqOf-v5A_CdpgnVfiiMM&r=N2JTMMRyUPP455WxaHP-1x2dgPYx4iyuxZq5ogP5UkQ&m=0r1Iiu3DjZZXz8jT47V2KkQpAHHJaAGubP6HzvysdMo&s=harCIxIFcygVwdt8Ynse85JbarPGaWoZVs4_MDKO6_A&e= Email chenry@oneidacity.com
> 109 N. Main Street Oneida, NY 13421
>
>
>
> -----Original Message-----
> From: Mary Jo Donaldson <mjdonaldson12@gmail.com>
> Sent: Monday, March 27, 2023 4:53 PM
> To: Christopher Henry <chenry@oneidacityny.gov>; Jim Szczerba <jszczerba@oneidacityny.gov>; Barb Henderson <bhenderson@oneidacityny.gov>
> Subject: Proposed wind turbine on Forest Ave/Brewer…
>
> Concerned neighbor regarding proposed wind turbine on Forest Ave/Brewer Road
>
> We have lived on Forest Ave., Oneida NY for forty one years. We purchased the land and built our home. We selected the area for its peace and quiet, spending enormous amounts of time outside.
>
> Years ago our neighbor on Vedder Road, built a small wind mill, before it broke it was extremely noisy. I can not imagine the noise that would come from a huge wind turbine. We strongly oppose the propose wind turbine that will be located north east of our property!
>
> Currently, we observe a field of solar panels located across the valley from our property and a land fill that has tripled in size. Certainly, not the beautiful view we had forty one years ago.
>
> The property owner lives in Sherrill, and this wind turbine would have no impact on his peace and quiet. I ask you, would you want a huge wind turbine in your neighborhood?
>
> John and Mary Jo Donaldson
> 4875 Forest Ave
> Oneida, NY 13421

> 315-363-8728
>
>
>
> Sent from my iPad

From:	Christopher Henry
To:	Kelley Hood
Cc:	Jim Szczerba; nollsark@yahoo.com; hoodgail1@gmail.com
Subject:	RE: Wind Turbine
Date:	Monday, March 20, 2023 12:41:00 PM
Attachments:	image001.png

Hi Kelley,

I appreciate you reaching out. I understand wind energy projects can raise a lot of questions, and it is my hope to provide some clarity. Please note that no official documentation has been submitted to the Department of Planning. We have seen some preliminary drawings, but nothing final or permanent yet. Please see my responses to your questions in the body of your email written in red.

Please feel free to call or stop by if you have any further questions.

Best regards,

Chris

Christopher Henry
Director of Planning and Development
City Phone: 315-363-4800 **Direct Line** 315-363-7467
Web www.oneidacity.com **Email**
chenry@oneidacity.com
109 N. Main Street Oneida, NY 13421

From: Kelley Hood <khood@hartic.com>
Sent: Sunday, March 19, 2023 8:36 PM
To: Christopher Henry <chenry@oneidacityny.gov>
Cc: Jim Szczerba <mri@twcny.rr.com>; nollsark@yahoo.com; hoodgail1@gmail.com
Subject: Wind Turbine

Hello Chris,

My name is Kelley Hood and I live on Brewer Rd. I was reading the minutes and monthly reports and noticed the applicant has resurfaced with the lifting of the moratorium. I also see that it says submission for PCZBA action is anticipated to be the end of March or April.

My mother-in-law, Gail Hood, and her friend/neighbor, Pamela Knoll, is very concerned about this project and how it will affect them, as well as other neighbors up here. I figured as everyone is talking, it's better to go right to the source.

We are hoping you can answer some questions please.

- Why does this say Brewer Rd when your last legal notice said Forest Ave? Did something change? Is it Forest Ave or Brewer Rd?
    - The original correspondence with my predecessor, Cassie Rose, had Forest Avenue. Codes just received a building permit that was denied today, and that says Forest Avenue. However, the legal address for the property per Real Property Services is Brewer Rd. I validated it with the City Assessor's Office. All PCZBA actions are required to have the legal location of the property. The best way to identify the parcel legally is through the Parcel ID Number which is 46.-2-42.3. We put both the street name and Parcel ID Number in all legal notices. The site has been referred to both street names in the past due to their proximity to both and both street names have been used in the course of internal discussions. However, for the sake of all official PCZBA actions moving forward, **Brewer Rd** will be used until an address is updated with Real Property Services.

- Do you plan on notifying the neighbors affected by letter or postcard?
    - It is important to describe some of the steps that the applicant must go through for PCZBA approval. Wind Turbines are required to get a Site Plan Review, Conditional Use Permit, and due to the size restrictions and national construction standards for windmills, an area variance is more than likely required for this project.
    - A part of our area variance procedures, require all adjacent property owners to be notified. This is through what is called a "Statement From Adjoining Property Owner" form. The City encourages the applicant to notify all adjacent owners via certified mail. The applicant is required to distribute the proposed plans. Proof of an attempt to notify neighbors must be submitted to the Planning Office prior to PCZBA action. This proof is submitted via a completed "Statement From Adjoining Property Owner" form or documentation deemed appropriate by the PCZBA. Typically, that is through documents provided by the certified mailing process.

- How do the neighbors get notified of the public hearing if no letter and when and how?
    - All legal notices are published in the Official Paper, the Rome Sentinel (Daily Sentinel). Additionally, all notices are placed on the City Website and the Planning and Development Facebook page. We typically get this published 5 days before the PCZBA meeting.
    - PCZBA meetings are every second Tuesday at 6:00 p.m. in the Common Council chambers. Any date and time changes are made public through a legal notice, with notices on the city website and Planning and Development Facebook page.

- What is the update New Leaf Energy had to work on to move this forward again?
    - The key thing was the moratorium had to be lifted. It is my understanding that prior to my starting in January 2022, they met with the City to discuss the project, which ultimately was stalled due to the moratorium. The moratorium was officially lifted with the new Wind Energy Law in January of this year. The Law had requirements which resulted in the applicant in making changes to their design. Again, no official final design has been submitted, so to identify what was changed would require an official

submission. It is my understanding that no final drawings were submitted to my predecessor, so it is difficult to identify what changed.

- What is the benefit of this wind turbine to the neighbors?
  - The benefit could result in an energy program that could save the City of Oneida on their energy bills. Through the Community Choice Aggregation Program through New York State. This is not official, nor has their any actions been taken by the city at this time.

- What does the applicant benefit as he will be the only one benefiting? He does not live up here.
  - As the benefits are negotiated privately, I am not aware of the extent of the applicants' benefit.

- I see there are 7 members on the Planning Commission. As these people get final say and not are elected officials. Is their contact information available to the public.
  - It is the policy of the City for all communication to the PCZBA be done through the Planning and Development Office. All e-mails such as this one will be provided to them through the PCZBA communications prior to any actions being taken. I encourage any comments be written, so they may be read un-altered by the members of the PCZBA. Also, the public hearing will allow the community to attend the meeting and provide comments related to the actions before the PCZBA members.

- Is there a location where a wind turbine is up already? That will give us all opportunity to view, listen and observe the windmill that will be interrupted in our neighborhood.
  - I believe the best nearby location to experience this is the Fenner Wind Farm at 5508 Bellinger Rd, Cazenovia, NY 13035. I would say the best thing to keep in mind that the Fenner Wind Farm is multiple windmills, where the proposed action on Brewer Road is one.

Please Pam and Mom, if I left something out, ask. You can also call Christopher Henry at 315-366-7467 ext. 135.

Looking forward to hearing from you.

Thank you!
Kelley

Gail Hood
1613 Brewer Rd
Oneida, NY 13421

Christopher Henry
Planning Commission/ZBA
Oneida City Planning Department
Oneida City Hall
109 North Main Street
Oneida, NY 13421

Dear Mr. Henry & Members of the Planning Commission,

I am writing to voice my concern for the Wind Turbine Project planned. First, this turbine project is aimed to be built in my back field which right now has a beautiful view that I enjoy. We have recently enjoyed the return of the bald eagle in our hills, and I'm concerned the turbine will be a deterrent. My house will be below where the turbine is to be built, which causes me concern for the noise level.

The entire hilltop is rock up here. When you fracture the rock due to drilling or dynamite you could possibly be causing danger to our wells, septic or basements which we have all made major investments in.

Over time Brewer Rd. accrued years of damage, which brought about large pot holes and rough driving conditions. It took years to get Brewer Rd back in shape after many years of potholes that our roads endured. These roads are not built for heavy equipment, and there is the possibility it brings us back to where we were years ago.

On a similar note, with the production of this project and even at completion of the project will be the noise levels. The creation of this will cause disturbance in a place where we have constant peace for an extended period of time. As well as the noise that will come from the turbine constantly after it is completed.

The water run off in the backfield of my property already has a sensational water run-off come spring time, or heavy rain. The creation of the turbine leaves me nervous that there could possibly be an increase in water run-off on our property.

The promises of this project to the city are vague, and most likely will not amount to much if free reign is given for the designation of this.

On a personal note, we built our home high on a rocky pasture to be away from all of the craziness, and live in our own peace. The view, sunsets, and sunrises have made us love our home. We have had the expansion of the Madison County Landfill bring foul odors drifting to the house especially in the summer, the hill full of windmills (who's power is sent downstate), and now the possible production of the Wind Turbine Project. Please re-consider this project to not destroy the landscape we have lived on for years, and for the sake of the home we cherish.

Thank you for your time and understanding my troubles and concerns regarding the Wind Turbine Project.

From: Pamela Spader Noll
To: Barb Henderson; Christopher Henry; Jim Szczerba
Subject: Wind Turbine on Forest Ave Concerns
Date: Monday, March 20, 2023 12:19:47 PM

Barb, Chris, Jim...

Please share this email with the members of the Zoning Board and Planning Board. Would also appreciate a reply back, that my concerns have been shared and taken into consideration.

I was notified that the application for the Wind Turbine on Forest Ave is up again for approval.

My name is Pam Spader Noll, I live at 1439 Brewer Rd (Noll's Ark Farm) and am one of the adjacent property owners.

Besides my fear of what this will do to my property value, I am very concerned how this will effect the wildlife (birds/bats that control the mosquito population) my farm animals, and of course the effect on human health!

I've attached the email (Exhibit A) below, that I received from my large animal Vet, after asking for their opinion on the effects to animals.

Who's going to repair my fences and potential property damage, if my animals freak out and break through them, who's going to chase them down and pay for Vet bills, if injured and damage of property? I'm worried about the comfort and safety of my animals and my own health!

Surely just the idea of endangering the wildlife/bats (mosquitos population), should be enough to be against this! Huge health risks!

Of course I'm aware of any studies, this company has paid for, will only benefit their position. And I don't believe any of their answers, they've addressed in their Q&A. I am not new to companies seeking approval of huge installations, as I was involved with the safety aspect of cell towers, during my working career @ AT&T/Lucent Technologies and into my retirement, as a consultant. They will tell you what you want to hear!

When they stated that farms and turbines can co-existence, that's because the farmers are making a profit, from having them use their land, as is this property owner will benefit, yet lives in Shirrell, and doesn't have to deal with the outcome.

I question this "single Turbine"...Surely, if this is approved, there's no stopping them from leasing more land, and installing more of these turbines, it would be cost effective.

Our once quite neighborhood will be highly disrupted by the construction of said Turbine. The traffic of heavy equipment, using our quite country roads, during this time (not to mention what it will do to our roads). Then there's the issue when it breaks down. They'll just abandon it up there and move on. (Too expensive to dismantal and haul away, proven fact)

I'm also very concerned about the "run off", as the Plans indicate, culver/drainage will be put in, directing water/dirt, straight down my back hill, where I'm connected to said land, and will run into my pastures, barn and home. This will be the same issue for all the neighbors surrounding this property, since we all live on the side of this hill.

The only ones benefitting from this installation will be the company and the property owner, not any of us! And this effects everyone up on our hill, not just the adjacent properties. Their voices/concerns need to be heard also.

All my neighbors have been expressing their concerns when the last application was submitted. You should be hearing from them also, as they are now aware, it up for approval again.

I have concerns with the noice study. They're talking in decibels, not frequency range, which should be a concern. They need to show data of what animals can hear, not just humans. Animals can detect much lower levels (decibel) so impact would be much greater than humans, and the frequency range, is also much different for animals....as they can hear further than us.

I've attached both a chart (Exhibit C) and link that addresses these concerns (Exhibit B)

These turbines need to be placed in more opened areas, and less populated, then on our hill, we call home.

I'm not comfortable with public speaking, therefore I'm sharing my thoughts and concerns with you, via email. I would greatly appreciate that you consider my concerns and vote against approving this installation.

Thank you so much for your time, in this matter.

Best regards,

Pamela Spader Noll
Noll's Ark Farm
1439 Brewer Rd
Oneida, NY
Email: nollsark@yahoo.com

Exhibit A (Vet's email)

> Hello Pam,
>
> Unfortunately there isn't a lot of studies done to show the affect of wind turbines on animals. All the studies available say more research needs to be done. It is noted that birds and especially bats are killed by the 10s to 100s of thousands by wind turbines. The problem here not only being loss of wildlife but the trickle down- bats eat several hundred mosquitoes a night, with less bats mean more mosquitoes and mosquitoes carry diseases that can kill or seriously impact animals (as well as humans). The high whine they emit also is thought to drive wildlife away, horses most certainly don't do well with wind turbines! They go nuts! A farm in Canada said their emus stopped laying eggs due to the noise when a wind farm was built near them and Europe has a lot of concern on wind farms especially UK and Sweden- they strongly recommend more research to be done before more of these farms are built due to wildlife and livestock potential impact.

Obviously the company will have their "data" saying all is wonderful but if they did the research for that data or paid a group to do the research for them, it cannot be trusted. Hope this helps.

Dr. Jen

Text from vet:

You most certainly can use my reply and I am fine if they want my name as well. Definitely am concern for your donkeys. I suspect the goats, sheep and alpacas will be stressed about it, they might eventually adapt. Hard to say. Yeah the bat/mosquito thing alone had me against wind turbines. We have enough mosquito born diseases!

Verona Veterinary Services
5633 State Route 31
Verona, NY 13478
Phone: 315-363-2691
Fax: 315-363-2662
veronavets@gmail.com

Exhibit B:

https://www.wind-watch.org/news/2012/05/11/do-wind-turbines-harm-animals/

Exhibit C:


How does an animal's hearing compare to a human's?
UK HEARING CARE.
Making Sense of Hearing...
Working with age UK
Love later life
As one of the five senses, hearing is important for helping us go about our daily lives. This is true not just for humans but animals too – all kinds of creatures across the world! Here we show you how a few animals' hearing compares to humans, and how they use it every day.
RANGE OF HEARING IN HERTZ (Hz)
0
30000
60000
90000
120000
150000
PORPOISE 75 150000
FACT: Despite having small ear openings on the side of their heads, porpoises and dolphins are thought to mainly hear through their lower jaw bones.
BELUGA WHALE 1000 123000
FACT: Beluga whales can spend months in constant darkness, so they rely on their hearing to navigate rather than sight.
BAT 2000 110000
FACT: Bats use echolocation, a system of soundwaves from their mouth or nose that can detect insects the size of gnats.
MOUSE 1000 91000
FACT: Mice can hear the most at aged 30 days, then at 50 days, this starts to degrade. When they are 20 months old, mice have significantly less sensitive hearing.
CAT 45 64000
FACT: Various liquid-filled canals in a cat's ears are what give them such great balance and can allow them to land on their feet
DOG 67 45000
FACT: Dogs hear best at higher pitches and are said to be able to tell the difference between their owner's and stranger's footsteps.
RABBIT 360 42000
FACT: Rabbits' large ears can help them hear up to 3km away and can rotate to help them identify where sound is coming from.
COW 23 35000
FACT: Cows have trouble pinpointing sounds compared to humans. They can pinpoint a noise within 30 degrees compared to humans' ability to pinpoint it to 5 degrees.
HORSE 55 33500
FACT: Horses turn their ears in the direction of the sound to help them hear.
SHEEP 100 30000
FACT: Sheep are frightened by high-pitched sounds such as fireworks or dogs barking.
HUMAN 64 23000
FACT: Humans carry on hearing when asleep, but our brains block out the sounds.
ELEPHANT 16 12000
FACT: Elephants use infrasonic sounds, which are below the human range to communicate over long distances (up to 1.5km).
OWL 200 12000
FACT: The ears of an owl are at different positions on each side of their head. They move their heads to find a point where the sound reaches the ears at the same time, it is then that they know the prey is in line with their face.
GOLDFISH 20 3000
FACT: Goldfish don't actually have ears, but can still hear sound. They have an inner ear located inside the fish's head, consisting of small bones that detect vibrations. They also have a lateral line that runs along both sides of the body from head to tail, detecting vibrations in the water.
CHICKEN 125 2000
FACT: Unlike humans, chickens can regrow hair cells in the inner ear, which means their hearing doesn't deteriorate with age and we even study them to help get insights into hearing loss.
TUNA 50 1100
FACT: Tuna have a similar basic functionality to humans, but are missing the earlobe and middle ear.
References
www.lsu.edu/deafness/HearingRange.html | www.academyhearing.ca/blog/news/Blog/2015/01/21/13/how-does-my-pet-s-hearing-compare-to-mine
www.thedodo.com/10-animals-with-amazing-hearing-1130711602.html | www.guinnessworldrecords.com/world-records/highest-frequency-hearing-animal
http://seaworld.org/animal-info/animal-infobooks/elephants/senses | www.dolphins-world.com/how-do-dolphins-hear | www.sheep101.info/senses.html
www.hearingsparks.com/2010/09/animal-hearing-series-cows.html | thegoldfishtank.com/goldfish-info/biology/can-goldfish-hear
http://idahoptv.org/dialogue4kids/season9/owl/facts.cfm | www.discoverwildlife.com/animals/mammals/why-do-rabbits-have-such-long-ears
www.scientificamerican.com/podcast/episode/beluga-whale-hearing | www.catster.com/lifestyle/cat-facts-ears | www.earthlife.net/fish/hearing.html

From:	Michael Evans
To:	Christopher Henry
Subject:	Windmills
Date:	Monday, March 20, 2023 11:05:04 AM

We do not want windmills built in Oneida. It will drop our property dollar value.

Dr. Michael Evans
mevans@eacc-services.com
315.729.9392

EACC
1078 Sugar Maple Drive
Oneida, New York 13421
https://urldefense.proofpoint.com/v2/url?u=http-3A__www.eaccservices.com&d=DwIFAg&c=euGZstcaTDllvimEN8b7jXrwqOf-v5A_CdpgnVfiiMM&r=N2JTMMRyUPP455WxaHP-1x2dgPYx4iyuxZq5ogP5UkQ&m=SODu24iKGlOHIepGT0ywU6Pzj8x_tX6uk_A0hidBS10&s=YwqQuf5cIqalTLXj9X5yBCsrjkdyHoAyiH2hPlDmt1A&e=

The form below has been submitted to all abutting property owners. Responses and/or proof of mailing will be provided to the City prior to a public hearing date.

Statement from Adjoining Property Owner

RECEIVED
APR 03 2023
City Clerk

To be completed by the Petitioner

Owner:
Oneida Wind 1, LLC. c/o New Leaf Energy

Project address:
0 Brewer Road

Requested variance:
Construction of a 560-foot (total height) wind turbine rather than a 450-foot turbine allowed under the City Ordinances.

I certify that the plans presented to the undersigned neighbor for his/her review are identical to those plans for which an Area Variance is being requested. *

[signature] Brandon Smith, New Leaf Energy, Applicant 3/21/2023
Signature of Owner Date

To be completed by the Neighbor

Name: DR. MICHAEL EVANS

Address: 1078 SUGAR MAPLE DRIVE

I have reviewed the above request for an Area Variance.

☐ ~~I have no objection to the above request.~~
■ I object to the above request.

[signature] 3-27-23
Signature Date

*Please Note: For ease of viewing, a single plan sheet has been included. PDF or paper copies of the full engineering plan set are available by contacting Brandon Smith at bsmith@newleafenergy.com or calling 978-221-3093

From:	Barb Henderson
To:	Christopher Henry
Subject:	FW: 2 interesting articles
Date:	Tuesday, July 18, 2023 11:23:45 AM

FYI. Please distribute to the PCZBA members. Thanks.

From: Pamela Spader Noll <nollsark@yahoo.com>
Sent: Tuesday, July 18, 2023 11:17 AM
To: Barb Henderson <bhenderson@oneidacityny.gov>
Subject: 2 interesting articles

Have you seen these yet?

Pam Spader Noll
Brewer Rd

https://wellsvillesun.com/blog/2023/04/17/farmer-wind-turbine-fire-in-rural-western-new-york-caused-contamination-to-family-livestock-and-land/

https://wellsvillesun.com/blog/2023/07/17/rexville-farmers-continue-to-pay-price-for-wind-turbine-fire/

Sent from Yahoo Mail on Android

From: Barb Henderson
To: Christopher Henry
Subject: FW: For Tom...please show him
Date: Friday, July 14, 2023 9:59:44 AM

FYI.
Please forward to the PCZBA members. Thanks!

From: Tracey Griffith <traceygriff@hotmail.com>
Sent: Thursday, July 13, 2023 8:32 PM
To: Barb Henderson <bhenderson@oneidacityny.gov>
Subject: Fwd: For Tom...please show him

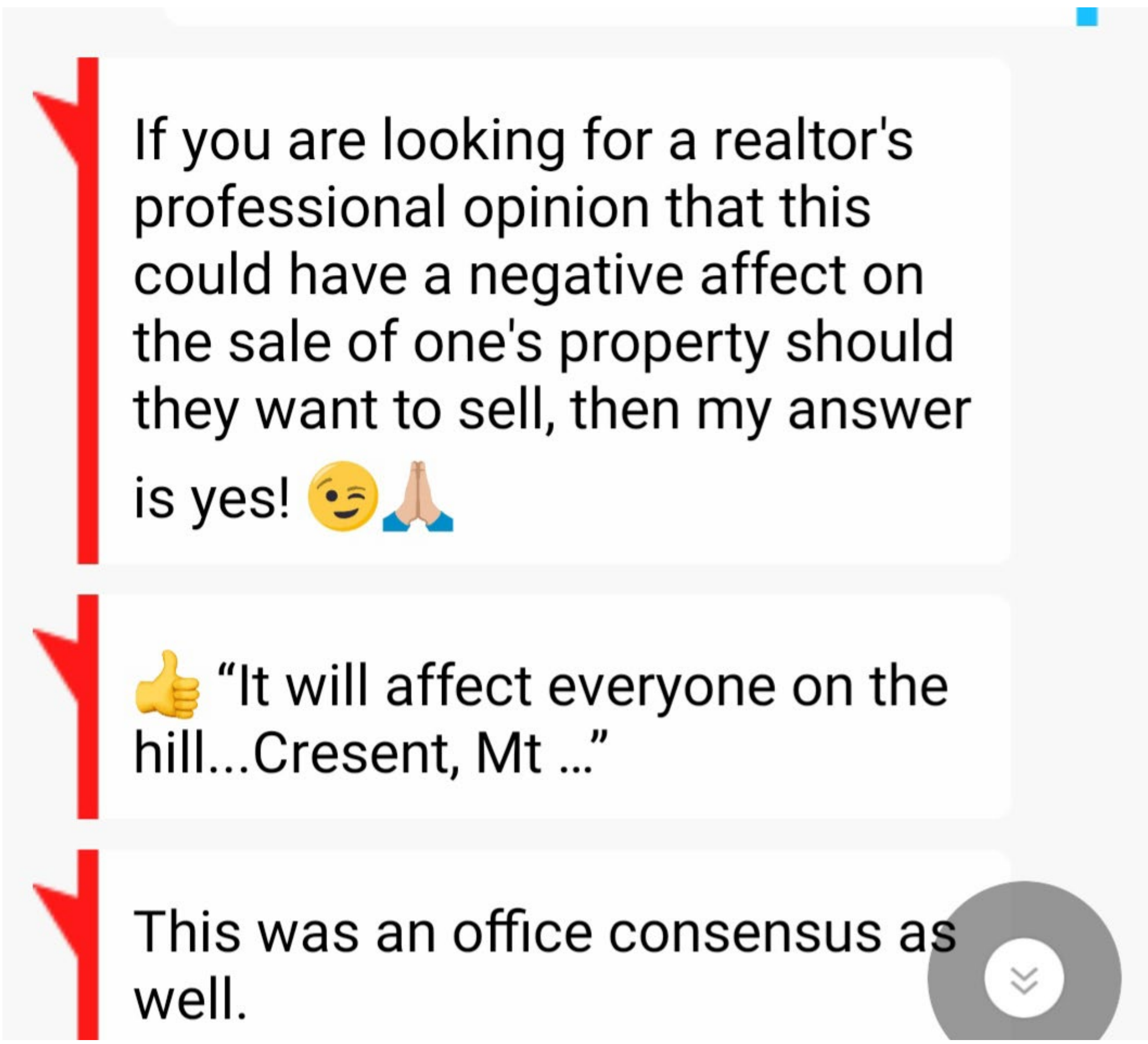
Here is more from a realtor that Pam contacted!

Thanks-

Tracey

Begin forwarded message:

> **From:** Pamela Spader Noll <nollsark@yahoo.com>
> **Date:** July 13, 2023 at 5:58:10 PM EDT
> **To:** Traceygriff@hotmail.com
> **Subject: For Tom...please show him**
> **Reply-To:** Pamela Spader Noll <pamspadernoll@yahoo.com>



otherwise...many of us in Real Estate & Home Appraisal's seem to be clear that the wind turbines do impact property values...

Forbes

- Michael McCann, of McCann Appraisal, LLC based in Chicago, **concludes** that: "Residential property values are adversely and measurably impacted by close proximity of industrial-scale wind energy turbine projects to the residential properties," up to 2 miles and a range of 25% to approximately 40% of value loss.

- John Leonard Goodwin, who has been a real estate broker for more than 10 years in Ontario, Canada, **reports** that wind turbines absolutely do impact property values: "Turbines complicate your property enjoyment, period. That alone spells depreciated value...they will also cause a significant loss of real estate value."

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<Screenshot_20230713_163802_Message+.jpg>
<Screenshot_20230713_163744_Message+.jpg>
<Screenshot_20230713_163512_Message+.jpg>

From:	Connie Burleson
To:	Jim Szczerba
Cc:	Christopher Henry
Subject:	O Brewer Rd/Forest Ave., Oneida NY
Date:	Wednesday, April 5, 2023 9:56:01 AM

As long time residents of Brewer Rd we object to the proposed project titled O Brewer Rd/Forest Ave Oneida NY.

Please consider the thoughts of the residents and tax payers living in this area when making the decision on this proposed project.

Thank you all for your time and work you have put into this project.
Please remember to ask your self would you want this in your back yard.

Sincerely.

Connie Burleson 1212 Brewer Rd

Gary Burleson 1529 Brewer Rd

Introduction to Research on Property Value Impacts

Concern for the impact of wind turbines on property values was a recurring theme in comments made to the committee by Township residents. Property value concerns raised by township residents include impacts of numerous very large turbines, night lighting and the impacts of an expanded electrical infrastructure with larger and more numerous electrical transmission lines and substations. While property values cannot be directly regulated through zoning, controlling factors that affect land values can minimize negative impacts. According to the Michigan Townships Association, the purpose of zoning is to "ensure the compatibility of land uses, protect natural resources and protect property values."

As documented in the attached document, the committee considered a variety of sources and research on property value impacts. *The Wind Energy Handbook* addresses tower size, view shed issues and also the associated issue that neighboring residents believe they are paying the cost of a financial benefit accruing to other landowners. The REPP study, *The Effect of Wind Development on Local Property Values,* which is frequently cited by wind farm developers, is seen to be incomplete and flawed by many, including David Maturen, a real estate appraiser in Kalamazoo, as he documented in a letter written to the MI Wind Working Group in 2005. The committee concluded that the impact on property values depends on location.

Large wind turbines can affect neighboring property values due to noise, health effects and visual impacts on residents. These adverse impacts on property values may not exist in agricultural areas that have huge farms. Centerville Township, however, allows 1 1/2 -acre residential parcels within agriculturally zoned land, and small residential parcels are scattered throughout the township. Adequate setbacks can minimize negative impacts and potential complaints from residents living near commercial wind turbines. The township supervisor of Lincoln Twp, WI told a committee member about problems that residents experienced after two public utilities constructed wind farms in Door County. Even residents living 1200-1500 feet from turbines complained of noise impacts and health problems. Several residences purchased by the power company were subsequently razed. In hindsight, the supervisor’s opinion was that many of the problems could have been avoided with 2,000' setbacks and 40 decibel noise limits.

Large wind turbines can also affect neighboring property values due to incompatibility with non-residential adjacent land uses. Centerville Township has large vineyards, and several wineries have opened tasting rooms within the township. The Centerville Master Plan states, "we encourage those tourist related enterprises which are locally owned and generate Economic benefit for the local area and people, as opposed to a tourist business where the economic benefit is exported out of the area." At the August 7, 2006 committee meeting, township resident Dan Matthies shared his recent experience as a real estate agent, specializing in vineyard properties. He had lost the sale of a large parcel within Centerville Township, because of the wind farm proposal by Noble Environmental. Based on Mr. Matthies' report, it seems a real possibility that large-scale wind development could seriously affect the agri-tourism business in Centerville Township.

DO WIND TURBINE GENERATORS AFFECT THE VALUE OF HOMES?

Findings
Yes, it is reasonable to conclude the presence of wind turbine generators (WTG) near residential housing causes property values to decline. This is common sense, and there are no serious scholarly studies that support an opposite conclusion.

Sources
Four reasonable source documents exist which discuss the impact on property values.

1. Wind Energy Handbook. Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi. John Wiley & Sons, New York, 2001.

2. "The Effect of Wind Development on Local Property Values." Renewable Energy Policy Project, May 2003.

3. "A Study of Wind Energy Development in Wisconsin." Energy Center of Wisconsin, July 1, 2004.

4. "The Net Benefits of Utility-scale Wind Generated Electricity in Western North Carolina." Todd L. Cherry, Appalachian State University, June 2004.

Common Sense
The most important citation is common sense. The old saying about residential real estate values is that price and salability depend on "location, location, location." The locating of a WTG near a residential house can, at best, have no effect on the value and salability of the house. That is, the presence of a nearby WTG might be a matter of indifference to a potential buyer. For example, if wind turbines were only five feet tall and made no more noise than an air conditioner, nearby properties would be unaffected. But logically, as wind turbines are larger and larger, in some cases 400 feet tall, and as they produce constant audible noise over a large area, as they intrude on the viewshed, the only valid conclusion is that nearby residences are less valuable than they would be if there was no turbine nearby. Why would a buyer choose a house within sight and sound of a turbine, if a comparable house at the same price were available elsewhere, beyond the sight and sound of the turbine? It is totally counter-intuitive to suggest anything else.

Property Values and Salability
Researchers do best when studying data that can be verified and replicated. Residential property values are subject to multiple variables at all times; so that isolating the effect of any one variable (such as the nearby presence of a WTG) is difficult. Particularly difficult is measuring the transaction that doesn't occur. In a buyer's market (which is currently a nationwide situation), a negative location factor can reduce the number of potential buyers significantly. This is, presumably, ultimately reflected in lowered prices, but some homes have been reported as "not salable" because of WTG proximity. This salability factor exists as common sense, it is probably significant, but is probably impossible to quantify statistically. There are no studies or surveys on this subject.

There are indeed some offsetting considerations for non-residential properties. First, if land (with a house on it) is being sold as fertile farmland, then the presence or absence of a nearby wind turbine is probably irrelevant. Second, if there is a chance that a future wind turbine might be placed on the farmland, a potential buyer might think the land was slightly more valuable.

Recently, in Centerville Township, a 150-acre real estate sale fell through when the potential buyer heard of the possibilities of wind turbines coming to the area. The buyer had a friend in Minnesota whose property value declined when a wind farm was located nearby. This buyer did not want to take a chance that the value of the property he wanted to purchase could decline also if a wind farm were to be located in Centerville Township.

Source: Wind Energy Handbook.
This is a comprehensive, pro-wind power textbook. There are these three references to viewshed and property values:

Page 513: "…their size makes visual effects a particularly important aspect of the environmental impact…

Page 513: "success or failure hinges critically on environmental considerations…and dialogue with…local inhabitants…"

Page 527: "In particular, there is the difficult issue that some local residents consider they are paying a high cost for a benefit, either financial or environmental, which accrues to others." (emphasis added)

Source: "The Effect of Wind Development on Local Property Values." (Renewable Energy Policy Project).
REPP is an outspoken advocate for wind turbine generators. They received a Federal grant to study the question of local property values. (It is common for researchers to be a proponent of a particular viewpoint, without their scholarship being impaired.) REPP's (unsurprising) conclusion: wind farms result in increased property values! The study is widely quoted, usually to make the point that there is divided opinion on the question.

The problem is, the REPP study is badly flawed. The flaws are
:

a. The study itself calculates several correlation coefficients, to prove the relevance of their data. But the data are not added up. Adding up the data gives a coefficient of 46%, which, in statistical terms, is inconclusive. That is, the data vary too much to be persuasive.

b. Ten projects were analyzed by REPP. Two of them were add-ons to projects begun fifteen years before. These two projects should have been excluded. Deleting them, the coefficient falls to 39%, which is approaching the conclusion that very little of the actual variation is explained by the analysis. A compilation of these data is attached.

c. The REPP study reached the remarkable (but wrong) conclusion that property values increased, but they did no follow up to verify this conclusion. Any credible researcher would then have used a simple follow up questionnaire to property purchasers (when the researchers had the names and addresses in front of them), which would have been such a verification. They failed to do so, thus making their conclusion not valid. A good researcher always double-checks the facts.

d. The REPP study only examined change in comparable property values over a three-year period. In most cases, the projects had been announced and debated long before the three-year window opened, so any depressive effect on property values would have occurred prior to the start of the study.

e. The REPP study did not look at other indices of real estate value, such as rising or falling inventory values, or the number of days from listing to sale. By limiting the study to <u>percentages of change</u>, the data can become tricky. Suppose two houses were each worth $100,000 ten years ago, and the value of one of them falls to $25,000 because a wind farm is announced. Then, if seven years later the first house sells for $110,000 and the second sells for $28,000, you can see that House One has an increase of 10% and House Two has an increase of 12%. So, REPP would conclude, that the owners of House Two are better off due to the presence of WTGs. In this hypothetical example, the REPP methodology would have ignored the 75% LOSS in value incurred when the WTG news first hit the papers.

f. And so on. Other criticisms of REPP are listed in the following sources.

<u>*Source: "A Study of Wind Energy Development in Wisconsin." Energy Center of Wisconsin*</u>
This is an objective study of WTGs, including the question of property values. The authors are unable to reach a definitive databased conclusion because of too few property transactions. This is a Catch-22 situation: wind farms are often located in areas of low population density; so that there never will be a statistically significant number of home sales transactions to analyze! However the Energy Center criticizes the REPP study as follows:

a. Part 3 page 125: REPP did not analyze whether the properties they studied "had a direct line of sight to the turbines."

b. Page 125: REPP "did not incorporate distance from the development as a variable…"

c. Page 126: "for a study such as (REPP) the real statistic is the confidence band surrounding the estimates…without these confidence intervals, it is impossible to determine whether the data…support any kind of conclusion…"

d. Page 135: "Nearly half of the property sales (in the Wisconsin study) could not be considered arms-length transactions." REPP ignored this element.

e. Page 137: "There are inherently opposing forces at work here, in the sense that while impacts on property values are likely to be strongest close to the development and taper off with distance, the number of property transactions decreases the closer one approaches the development. This…undermine(s) the credibility of the REPP study conclusion that 'there is no support for the claim that wind development will harm property values.'"

<u>Source: "The Net Benefits of Utility-scale Wind Generated Electricity in Western North Carolina." Todd L. Cherry</u>
This paper supports a wind project proposed for North Carolina.

a. Page 13: "The empirical results (of the REPP study)…may be questioned on empirical methodology issues shown to be substantially influential on the results."

b. Page 15: "Installing turbines that negatively impact property values essentially takes an attribute of the property that the owner paid for within the purchase price."

c. Page 19: "The most significant…indirect cost is likely the impact on property values (i.e. viewshed)—with it possibly being a larger problem in western North Carolina…due to the region's scenic vistas being such a vital component of its quality of life and economic development."

d. Page 23: "Long term economic development for the local area (meaning jobs and tax revenues) will be minimal."

e. Page 36: In an elaborate table of economic plusses and minuses, Professor Cherry states:

1. "The calculation conservatively assumes viewshed and noise impacts on 500 houses valued at <u>an average of $25,000 per house</u>." (emphasis added)

2. "The net property tax effect is zero."

This last point is important in this discussion. Whatever property value appreciation accrues to landholders who permit installation of WTGs, is exactly offset by the property value depreciation accrued to all other landholders in the area. So the WTG lessee incurs a higher property tax and receives annual rent for signing the lease/easement as more than offsetting compensation. The other landholders find their property values decreased, and they receive nothing. The township has no net gain or loss on property taxes.

<u>Other Sources: Letter from David Maturen, Appraiser, Kalamazoo Michigan, to "Michigan Wind Working Group" dated July 17, 2005</u>
In his letter, Mr. Maturen cites several studies that were based on surveys of real estate agents in Europe and the United States. These studies did not have the rigor of true research. They all support the position that real estate values declined when WTGs were installed.

<u>Other Sources: Renewable Energy Systems, Great Britain, Frequently Asked Questions</u>
This pro-wind resource cites a study by the Royal Institution of Chartered Surveyors (RICS) in England. Despite the claim that "there is no conclusive evidence" regarding impacts on property values, the details provide reasonable evidence that there is a negative impact.

Page 3: "The results of the RICS study clearly demonstrated that…60% of the sample suggested that wind farms decrease the value of residential properties where the development is within view…"

Page 3: "Those living nearest to wind farms are their strongest advocates." The RICS study looked at long-established wind farms. Obviously, opponents of wind farms had moved away. Even so, these advocates were part of the 60% who experienced declines in property values.

Conclusion

Some people have written, "The jury is still out on this question." Presumably people have this view because of the REPP study, which concluded, erroneously, that the presence of wind turbines caused property values to rise! Admittedly, the question of the impact of WTGs on property values is difficult to analyze, and the results difficult to quantify. Many factors affect property values: supply and demand, interest rates, cost of new construction versus prices of used homes, availability of utilities, etc. So, in addressing the question of the impact of WTGs on property values, we can look at the available evidence and make an informed conclusion, using the data that we have, and using common sense.

That conclusion is the presence of WTGs negatively impacts property values. The amount of impact is as high as $25,000 per residence. Overall salability of properties probably declines. The economic benefit to the lessee of the wind development rights is an equal economic detriment to the surrounding residences.

Richard Light
Molly Hyde
Centerville Township, August, 2006

Notes:

1. Some may argue that the nearby presence of a WTG would encourage wind power proponents to purchase a home. While this is theoretically possible, there is no evidence to support it. The purchase of a home is the largest purchase a person makes. Despite individual preferences, the resale of that home is usually a factor in deciding to buy. Thus, a purchaser who is deaf might not care that there is significant noise from a nearby freeway, but the purchaser would recognize that subsequent salability of the home is a factor to consider.

2. Is it fair to dismiss the REPP study completely? In fact, the work of the analysts was very thorough and appears objective. The problem is, the results are so surprising that they needed to be verified, but they were not. The paper was not subjected to peer-review, as any good scholarly work should have been. The three comprehensive, serious studies (which are otherwise pro-wind) subsequent to REPP are completely dismissive of its findings. Yes, it is fair to dismiss the REPP report.

3. Why did REPP publish its results without verification and without peer review? In its paper, REPP laments that its funding ran out so there were questions they did not pursue. It is a reasonable conjecture that they were delighted with their results and did not seek additional funding. They likely concluded, rightly, that any research finding, no matter how flawed the scholarship, that showed no property value decline, would be disarming and confusing to critics of wind power.

4. If it is so obvious that property values decline, why aren't there persuasive data to prove the point? Wind farms exist in many differing locations and are of significantly different sizes. A wind farm in the North Sea off the coast of Denmark is difficult to compare to a proposed Centerville Township project. Wind turbines 150 feet tall in a California desert are similarly difficult to compare. Some wind farms have less than ten WTGs; others have hundreds of WTGs. Importantly, in several European wind developments, the adjacent property owners participate in the economic benefits, through reduced electricity bills: this outcome would certainly be a positive economic influence on attitudes of current property owners and of potential buyers. Further, large wind farms in populated rural and scenic areas are a very recent development. Sufficient time must pass before trends and valid comparisons can be established. By the time such comparative data bases are established and analyzed, decisions about new wind farms will have been made and implemented.

From:	Pamela Spader Noll
To:	Barb Henderson; Christopher Henry; Jim Szczerba
Subject:	Proposed Wind Turbine (Part 2)
Date:	Thursday, April 6, 2023 10:52:45 PM

Barb, Chris, Jim,

I need to add to my previously email, after receiving the full set of plans for the proposed Wind Turbine.

Now I see the culvert is being diverted towards Forest Ave, but this doesn't correct my concerns about the additional water run off, towards my property. Drilling or blasting and vibration of the blades, will only create more cracks in the fractured rocks, which this hill is made up of, and will cause even more damage to my property. Who will be responsible to pay for damages to property owners? (foundations, wells, septic, building structures, etc)

I live on the cliff side of this sites property, my next door neighbor's house, being the closest dwelling to the site.....so yes, I'm very concerned with what can happen, as a result, if this is approved.

The current run off after a heavy rain and Spring thaw, has washed our driveways (on Brewer side) completely out. We ended up having to go with the expense of blacktop, but I still have to deal with the flooding of pastures and lawn. More cracks in the rocks will only increase the problems, especially with the septic. (Photo attached of pooling of water from run off, collecting over leach field)

**(Attached photos are from this mornings run off, after last night rain) I have videos of the water gushing out of the fractured rocks, but unable to attach to an email. If someone is willing to give me a cell phone number, I can text those videos for you to view. It's amazing to see...

I also own 5 acres across the road, which is lower. What will happen to that land, with the increased run off?

We request that you contact both a Wildlife Biologist and Zoologist at Cornell, to get their input on how this will effect our Wildlife (I'm sure they'd be concerned about the Bald Eagles we have living up here), farm animals and domestic pets, before any decisions are made.

Am still very concerned with our property value, who would buy my house with this monstrosity behind it? I sure wouldn't! (attached photos of the test pole, that can be clearly seen, and I've marked where my property ends, near top of the ridge line). Just imagine the enormous Turbine I'll be looking at. The noise alone will be unsettling, as sound travels downwards.

We all moved up here to enjoy the quite country life. Not to be paying high taxes, for this unsightly monster to deal with. Don't we get a say?

These things belong out in open land, with no houses around, not on our hill! Again, who is benefitting, for what "we" would be dealing with?

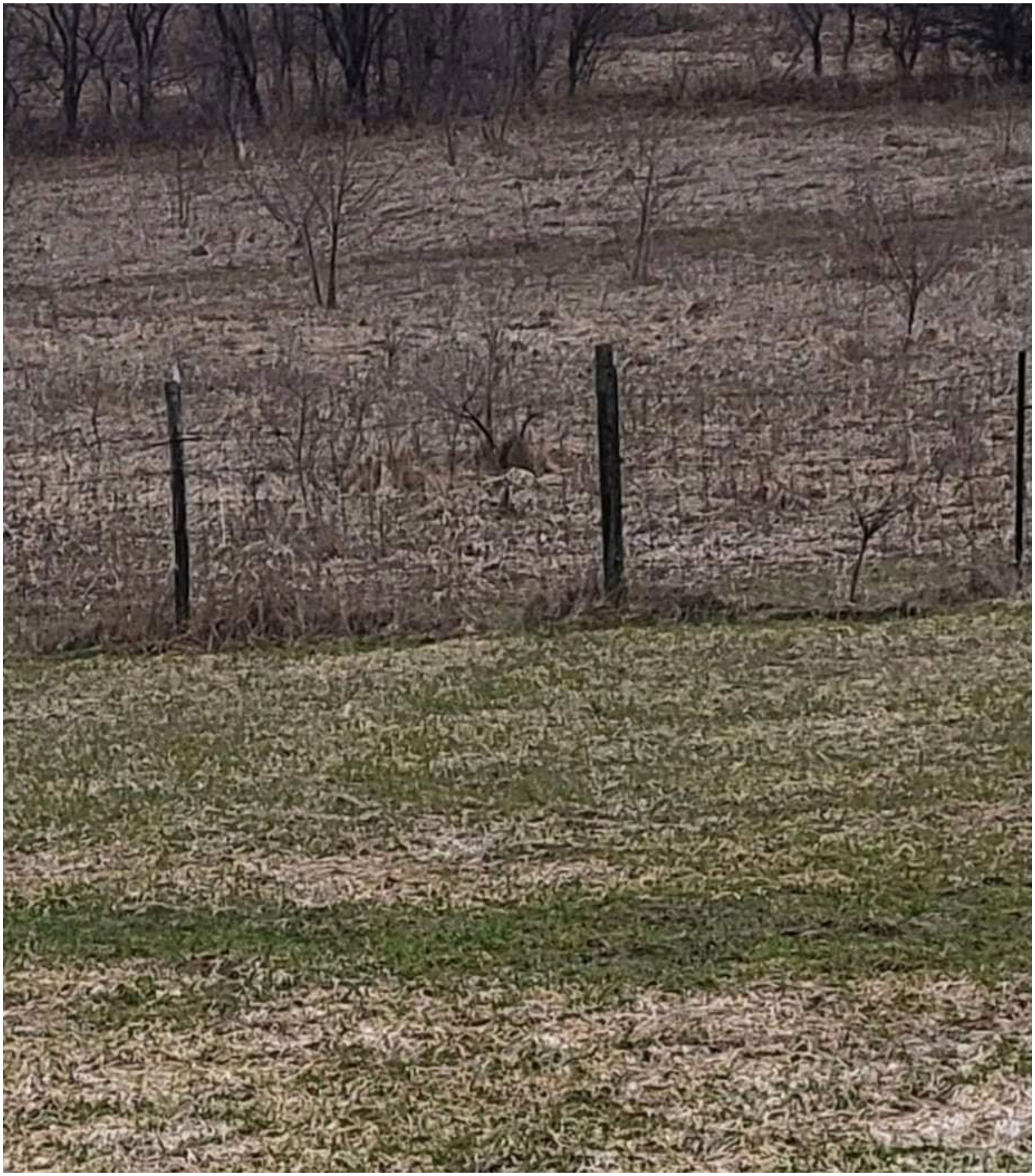
Has anyone on the board, taken a ride up here, to see the location and the location of surrounding homes and properties? Think every member needs to do that, and not just look at a map. I personally invite each one of you, to come see my property, as you can not view it from the road.

Please pass along to all board members.

Regards,

Pam Spader Noll
Noll's Ark Farm
1439 Brewer Rd.

Test pole as viewed from my pasture

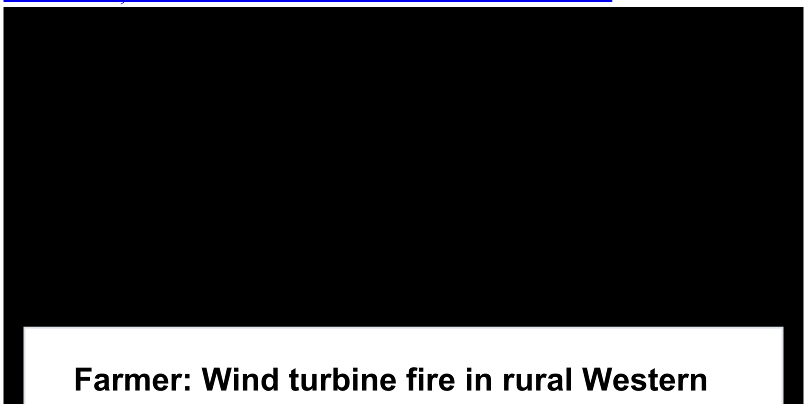



My Property

Water gushing from the fractured rocks, this is just one small area

From: Pamela Spader Noll
To: Barb Henderson; Christopher Henry; Jim Szczerba
Subject: This just happened 3 hrs away!
Date: Wednesday, April 19, 2023 7:46:51 AM

Farmer: Wind turbine fire in rural Western New York caused contamination to family, livestock, and land - THE WELLSVILLE SUN



Farmer: Wind turbine fire in rural Western New York caused contamination to family, livestock, and land - THE WELLSVILLE SUN

Fiberglass particles drifted downwind during the Rexville fire By Andrew Harris The scenes were amazing from the recent fire on the Steuben-Allegany county line. A massive wind turbine was on […]

From:	Linda Perry
To:	Christopher Henry
Subject:	Wind turbine
Date:	Tuesday, April 4, 2023 6:12:39 PM

We are against having a big, ugly, loud wind turbine erected on our hill. Crescent Ave. The people profiting from this don't even live up here.
The fantastic view and peaceful atmosphere is the main reason most homeowners live up here.
Remember that we pay a lot of taxes up here and such a monstrosity will surely lower our assessments. Think hard before considering approval!

Linda and Richard Perry
Crescent Ave.

Sent from my iPad

From:	Michael Evans
To:	Christopher Henry
Subject:	Windmills
Date:	Monday, March 20, 2023 11:05:04 AM

We do not want windmills built in Oneida. It will drop our property dollar value.

Dr. Michael Evans
mevans@eacc-services.com
315.729.9392

EACC
1078 Sugar Maple Drive
Oneida, New York 13421
https://urldefense.proofpoint.com/v2/url?u=http-3A__www.eaccservices.com&d=DwIFAg&c=euGZstcaTDllvimEN8b7jXrwqOf-v5A_CdpgnVfiiMM&r=N2JTMMRyUPP455WxaHP-1x2dgPYx4iyuxZq5ogP5UkQ&m=SODu24iKGlOHIepGT0ywU6Pzj8x_tX6uk_A0hidBS10&s=YwqQuf5cIqalTLXj9X5yBCsrjkdyHoAyiH2hPlDmt1A&e=

From:	Barb Henderson
To:	Christopher Henry
Subject:	FW: Concers over infrasound generated by wind turbines
Date:	Friday, July 14, 2023 10:14:16 AM
Attachments:	Study2-SoundPressure.pdf Study3-HumanEffects.pdf Study4-EffectsOnLivestock.pdf Study5-EffectsOnGeese.pdf Study1-Stochastic_and_Modulated_.pdf

FYI. Please note his request to read this email at the next PCZBA meeting separately from the 3 minutes allocated per speaker.

From: Rob <rob.coapman@gmail.com>
Sent: Thursday, July 13, 2023 7:57 PM
To: Christopher Henry <chenry@oneidacityny.gov>; Barb Henderson <bhenderson@oneidacityny.gov>
Subject: Concers over infrasound generated by wind turbines

To the Oneida City, New York Planning Board,

re:proposed wind turbine on Forest Rd

Infrasound is sound energy that is generated at frequencies too low for human hearing but is experienced as 'sound pressure' vs what we would normally refer to as audible sound. This type of sound is generated at significant energy levels by the operation of large wind turbines. (Baumgart et al., 2017)

I have attached 5 research paper on the properties of infrasound or the various impacts that infrasound has on humans and animals that I will also directly reference in this email. If you have ever had a vehicle drive past you with loud music with heavy bass and felt a pressure in your chest, that pressure is due to infrasound.

It is true that the research on infrasound and wind turbines is in its very early stages and much remains to be learned. However, there is sufficient initial indications of impact on humans and animals to cause concern over building an infrasound generator close to human habitation and animal populations.

If you look at studies numbered 4 and 5 in the attachments to this email, you will see that populations of pigs and geese reared at various distances away from wind turbines show significant biochemical markers of stress, such as dramatically increased cortisol levels, in direct correlation with how close they are to the turbines. (Karwowska et al., 2015; Mikolajczak et al., 2013) Karwowska et al. (2015) found that pigs raised in close proximity to wind turbines had lower meat quality and quantity as compared to those raised farther away. There was a similar decreasing gradient of iron in the blood (heme iron) the closer the pigs were to the turbines and an increase in α-linolenic acid, and indicator of oxidative stress. (Karwowska et al., 2015).

Mikolajczak et al. (2013) found that geese raised in proximity to wind turbines had ~10% lower body weights, partially attributed to reduced appetite. This loss of appetite may be causally related to the increase in the stress hormone cortisol, also noted to be higher in geese raised closer to the turbines. (Mikolajczak et al., 2013)

While I am not aware of any farms raising pigs or geese in the immediately vicinity of the proposed turbine site, the evidence clearly indicates that the infrasound generated by these wind power generators can have significant negative impacts on the health and well-being of animal populations. There is a large deer population that lives in this area that could very conceivable be driven off due to disturbance caused by infrasound. This would not only remove these lovely creatures from our yards but also poses a risk of these deer being struck by cars as they migrate. They may move into areas already heavily populated with deer causing starvation or further migration due to limited forage and other resources.

The evidence for impact on humans is admittedly less clear but this should not be interpreted as a lack of impact, merely as a lack of full understanding as comprehensive research appears to have not been done on this subject and also limited by the ethical considerations always present when humans are involved in research.

I have already mentioned that infrasound is perceived as 'sound pressure' vs what we normally think of as sound. This sensation can be distracting, or, worse, unpleasant, depending on the amount of energy, or what we think of as 'volume', in the sound waves.

I would add that it would personally be fairly angering, if not enraging, to have this sensation, at any level, forced upon me 24/7 in my own home.

In a pilot study using proxies for turbine-generated infrasound in addition to control sources, Malecki et al. (2023) found that subjects exposed to wind-turbine sound energy more commonly reported "pressure changes in the head, experience of physical or mental discomfort" more commonly than did control groups. There were also significant differences in reported experiences of men and women- men more commonly noted pressure and condition changes whereas women 'felt 'worse after the exposure. (Malecki et al., 2023)

The same study found no direct impact on cognitive abilities in any of the test conditions.

Flemmer & Flemmer (2023) describe that infrasound is comprised a different wave form than audible sound and can actually increase in volume over distance in certain situations. This means that the typical condition of sound softening over distance may not fully apply to infrasound and that normal tolerances provided by the wind industry re: audible sound are not accurate metrics to determine the impact of this low frequency noise. Infrasound also loses less energy per unit of distance, meaning it carries farther, due to the longer wavelengths involved. (Flemmer & Flemmer, 2023)

Flemmer and Flemmer's (2023) comprehensive review did note that many of the psycho-biological effects reported by human subjects increased when they believed the sound came from a wind-turbine, but this should not be discounted. The experiences of these individuals are quite real and the fact that they be exacerbated by their own frustration or anger is an important factor to consider in weighing the impact a wind turbine will have on their quality of life.

There appears to be a high degree of individuality in the response to wind-turbine generated infrasound. Some people become habituated to its presence whereas some become increasingly hypersensitive, some are more aware of the presence of infrasound than others, etc.

There is also the matter of audible sound. Though the developers insist that after a certain distance the turbine is not very loud, 'loud' is a relative term. 45dB is not very loud when it is blending in to the background of a city street but in a quiet, country location such as where I live 45dB may be quite disruptive. When I am in my yard in the early morning I am able to hear the air moving across the flight feathers of a gliding bird over 50ft away. Many of us chose to live here in no small part for the pristine quiet of these moments and are unwilling to give them up. Even a small source of noise would be cacophenous here.

While renewable energy can and must be utilized instead of carbon-emitting fuels to curtail the accelerating impact of climate change, this single wind turbine is being proposed in an ill-considered location. In addition to the fragile water supply for residents, there appears to be a statistically and scientifically significant risk for negative impact to both human and animal populations due to the little understood impacts of persistent sub-audible environmental sound energy.

I respectfully submit these comments to the planing board for your consideration in addition to those made by myself and other residents at the planning board meeting on 12JUL23.

I would also request that I be allowed to read the contents of this email at the next board meeting and have this reading placed on the agenda, not as part of the time-limited public hearing.

Regards,
Robert Coapman
4919 Forest Ave
Oneida, NY

Citations

Baumgart, J., Fritsch, C., & Marburg, S., (2017). Infrasound of a wind turbine reanalyzed as power spectrum and power spectral density. *Journal of Sound and Vibration*, 388, 188-200. doi:10.1016/j.jsv.2021.116310

Flemmer, C. & Flemmer R. (2023). Wind turbine infrasound: Phenomenology and effect on people. *Sustainable Cities and Society*, 89. doi:https://doi.org/10.1016/j.scs.2022.104308

Karwowska, M., Mikołajczak, J., Dolatowski, Z.F., & Borowski, S. (2015). The effect of varying distances from the wind turbine on meat quality of growing-finishing pigs. *Annals of Animal Science*, 15(4), 1043-1054. doi:10.1515/aoas-2015-0051

Małecki, P., Pawlaczyk-Łuszczyńska, M., Wszołek, T., Preis, A., Kłaczyński, M., Dudarewicz, A., Pawlik, P., Stępień, B., & Mleczko, D. (2023). Does Stochastic and Modulated Wind Turbine Infrasound Affect Human Mental Performance Compared to Steady Signals without Modulation? Results of a Pilot Study. *International Journal of Environmental Research and Public Health,* 20(3), 2223. https://doi.org/10.3390/ijerph20032223

Mikołajczak, J.,Borowski, S., Marć-Pieńkowska, J., Odrowąż-Sypniewska, G., Bernacki, Z., Siódmiak, J., & Szterk, P. (2013). Preliminary studies on the reaction of growing geese (*Anser anser f. domestica*) to the proximity of wind turbines. *Polish Journal of Veteriniary Sciences*, 16(4), 679-686. doi:10.2478/pjvs-2013-0096

International Journal of
Environmental Research and Public Health

Article

Does Stochastic and Modulated Wind Turbine Infrasound Affect Human Mental Performance Compared to Steady Signals without Modulation? Results of a Pilot Study

Paweł Małecki [1,*], Małgorzata Pawlaczyk-Łuszczyńska [2], Tadeusz Wszołek [1], Anna Preis [3], Maciej Kłaczyński [1], Adam Dudarewicz [2], Paweł Pawlik [1], Bartłomiej Stępień [1] and Dominik Mleczko [1]

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[2] Department of Vibroacoustic Hazards, Nofer Institute of Occupational Medicine, 91-348 Lodz, Poland
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* Correspondence: pawel.malecki@agh.edu.pl

Abstract: Wind turbines (WT) are a specific type of noise source, with unique characteristics, such as amplitude modulation (AM) and tonality, infrasonic and low frequency (LF) components. The present study investigates the influence of wind turbine infrasound and low frequency noise (LFN) on human well-being. In the between-subjects study design, 129 students performed a cognitive test evaluating attention and filled out questionnaires in three various exposure conditions, including background noise, synthesized LFN (reference noise) and registered WT infrasound (stimulus). No significant differences in test results or in the number of reported post-exposure feelings and ailments in various exposure conditions were found when analyzing them in males and females, separately. However, a significant association between pre-exposure well-being and reported post-exposure complaints was noted and explained by in-depth statistical analysis.

Keywords: infrasound; low-frequency noise; wind turbine; effects on humans; infrasound playback

Citation: Małecki, P.; Pawlaczyk-Łuszczyńska, M.; Wszołek, T.; Preis, A.; Kłaczyński, M.; Dudarewicz, A.; Pawlik, P.; Stępień, B.; Mleczko, D. Does Stochastic and Modulated Wind Turbine Infrasound Affect Human Mental Performance Compared to Steady Signals without Modulation? Results of a Pilot Study. *Int. J. Environ. Res. Public Health* **2023**, *20*, 2223. https://doi.org/10.3390/ijerph20032223

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1. Introduction

Infrasound (IS) and low frequency noise (LFN) are ubiquitous in modern industry, the environment and urban lifestyle. The most common sources of infrasound are: traffic, large ventilation systems, public transport, wind farms, heat pumps and large machines [1,2]. Most of the reviews concerning the impact of infrasound on health have been based on data related to industrial workers or observations of areas exposed to infrasound due to their proximity to sources [3–5]. Such research is usually burdened with high ambiguity. For example, low-frequency audible components usually occurred during the exposure, which precluded an unambiguous answer to the question of whether the adverse effects can only be attributed to infrasound or audible bands. Accordingly, the most recent reviews of studies on the influence of infrasound on human health adopt conservatism while making conclusions about the adverse health effects directly caused by infrasound. Psychological and social mechanisms have been suggested as contributory factors to annoyance, which explains the observed adverse health effects better than exposure to very-low-frequency noise [6]. According to another report, about 10% of people living near infrasonic sources report general annoyance [7].

Most previously cited reports usually highlight the potential side effects, such as nausea, malaise, fatigue, undefined pain, sleep disturbance or irritability. However, there are also reports [8,9] signaling the potential use of infrasound in oncological therapy as support for the treatment with positive effects. A special case of infrasound is the phenomenon of binaural beats, which can be used in relaxation and sleep therapies [10,11], and the cited studies additionally indicate changes in the EEG (Electroencephalography) signal identical to exposure to infrasound.

Despite the indications regarding the effects of infrasound on mental health and cognitive functions in humans previously mentioned or reported in the literature, there are virtually no studies that directly investigate infrasound effects on human health in a randomized and controlled manner. In addition, so far there have been no studies analyzing the effect of infrasound on brain structure besides one piece of work [12] in which the effect of long-term human exposure to infrasound compared to a placebo was analyzed in a randomized manner. The presented study proves that long-term exposure (1 month) to infrasound with an amplitude above the values observed in wind farms and with a frequency of 6 Hz does not affect human behavior. This includes a number of variables related to health and psyche (i.e., self-assessment of noise sensitivity, sleep quality, psychosomatic symptoms or tension) and cognitive functions (i.e., alertness, constant attention, cognitive flexibility, divisive attention, attention shift and inhibition). At the same time, it has been observed that exposure to infrasound is associated with a decrease in gray matter in areas of the brain that are associated with somatomotor and cognitive functions, such as working memory (bilateral VIIIa cerebellum) and higher auditory processing (angular gyrus, BA39), including functions, such as speech intelligibility/production or semantic/lexical processing and reading. In another study on the influence of infrasound directly on the brain [13], it was noted that exposure to infrasound caused a change in the BOLD (blood oxygen level-dependent) signal in the primary auditory cortex and superior temporal gyrus. These are areas in the brain that are largely responsible for higher order auditory processing, such as language comprehension.

Wind turbines are a specific type of noise source, with an impact on large areas. The noise emitted by wind turbines does not resemble common industrial noise [14,15]. It has specific acoustic characteristics, such as amplitude modulation (AM) and tonality [16], as well as LFN and IS components, which can contribute to higher perceived annoyance [17,18]. Recently, Turunen et al. [19] carried out the first large-scale questionnaire study examining symptoms intuitively related to infrasound by people living near wind turbines in Finland. Nearly half of them reported ear symptoms; 26% cardiac symptoms; 24% headaches; 21% dizziness; 9% fatigue, high blood pressure or joint aches; and 7% nausea and difficulty focusing. In addition, 40% of symptomatic respondents reported negative effects on their health and 29% on their ability to work. The aforementioned study revealed that 70 out of 1351 respondents (5%) reported symptoms, which they attributed to infrasound from a wind farm. The symptomatic respondents lived closer to the wind farm than the asymptomatic respondents. Furthermore, they more often suffered from chronic diseases, complained about the annoyance of wind turbines and believed that wind turbines posed a health risk. Moreover, out of all the respondents, 10% considered wind turbine infrasound as a high risk to personal health and 18% as a high risk to health in general [19].

Although a great deal of research has been carried out over the years to evaluate adverse effects of different kinds of noise, it mostly concerns noise at rather high levels and/or occupational exposure, whereas studies of infrasound and LFN, in particular, at low SPL, are rather scarce [20,21]. Furthermore, most of the previous laboratory studies on the IS and LFN effects on cognition functions gave inconsistent results and did not allow the determination of noise threshold values above the level at which this effect occurs. For example, Moller [22] analyzed equal annoyance curves for pure tones in the frequency range of 4 Hz–31.5 Hz and found that when IS and LFN become audible, a slight increase in SPL leads to a large increase in annoyance. In turn, Persson et al. [23] compared annoyance related to LFN and noise without prominent content of low frequencies but at a similar A-weighted SPL and found that LFN was more annoying and more difficult to adapt. Similarly, Kjellberg et al. [24] investigated two types of noise with SPLs in the range of 49–86 dBA and frequencies from 15 and 50 Hz in twenty subjects. At the same A-weighted levels, LFN was perceived as 4–7 dB louder and 5–8 dB more annoying than higher frequency noise. Moreover, some previous studies generally indicated that LFN at levels that could occur in the occupational environment, including those typical for office-like areas and industrial control rooms (40–60 dBA), might be assessed as annoying and reduce the human mental performance, particularly when executing more demanding tasks [25–27]. Moreover, subjects classified as sensitive to noise might be at higher risk.

Substantial attention has also recently been focused on investigating human responses to wind turbine noise. Laboratory experiments complement field surveys as they provide a more controlled environment needed to analyze causal relationships between characteristics of wind turbine noise and some of its effects [28]. According to a recent literature review by Karasmanaki [29], the effects of wind turbine noise on individuals' health, sleep, cognitive performance and annoyance have been investigated by a significant number of experiments and listening tests. Even though these studies examine the impact of short-term rather than long-term exposure to wind turbine noise, they provide objective observations, which could be used to verify residents' reports of WTN impacts recorded in quantitative research. However, only a few studies have, to date, been performed concerning the impact of wind turbine IS or LFN, while the majority of them focus on wind turbine noise in general. For example, such experiments were recently performed as part of a larger research project commissioned by the Finnish Government's Analysis Assessment and Research Activities [30]. They were aimed at the assessment of contributions of infrasound to the perception, annoyance and physiological reactions elicited by wind turbine sound. Sound samples recorded inside and outside residential houses near wind turbines with the highest infrasound levels and depth of AM were chosen for laboratory investigations. In the aforementioned experiments, the detectability and annoyance of both inaudible and audible characteristics of wind turbine noise were determined, as well as autonomic nervous system responses: heart rate, heart rate variability and skin conductance response. The participants were divided into two groups based on whether they reported experiencing wind turbine infrasound-related symptoms or not. It has been shown that people who have reported symptoms related to infrasound showed no increased sensitivity to wind turbine infrasound (i.e., they did not detect infrasonic contents of wind turbine noise). Total wind turbine SPL and amplitude modulation resulted in increased annoyance not infrasound. In turn, the wind turbine infrasound or wind turbine sound annoyance were not related to either heart rate or heart rate variability or to skin conductivity (physiological measures of stress). The presence of infrasound had no influence on the reported annoyance or the measured autonomic nervous system responses. No differences were observed between the two groups. These findings suggest that the levels of infrasound in the current study did not affect perception and annoyance or autonomic nervous system responses, even though the experimental conditions corresponded acoustically to real wind power plant areas.

The main aim of the current study is to investigate whether the IS and LFN accompanying the operation of wind turbines in Poland affect human well-being. In particular, an attempt has been made to answer the question of whether modulated IS and LFN can negatively affect mental performance compared to signals without modulation.

2. Methodology

2.1. Stimuli

The main goal of the experiment was to examine the IS and LFN generated by wind turbines, with the first step being to accurately capture the proper stimuli for the experiment. First, preliminary recordings and sound pressure measurements were conducted in the Kościuszko ventilation shaft of the Wieliczka salt mine near Krakow, Poland in order to verify the usefulness of the planned recording equipment in the measurements of IS and LFN. This source was chosen because it generates low-frequency band noise regardless of the wind conditions.

The in situ recordings were conducted on wind farm E (anonymous due to the agreement with the farm operator) at a distance of 130 m from the turbine on 9 July 2021 and on farm A at a distance of 250 m from the turbine shown in Figure 1. Due to the more stable weather conditions, since there was no wind on the microphones' membranes during all turbine nominal work for at least 10 min, recordings from wind farm A were used in the following parts of the experiment.

Figure 1. The wind turbine noise measurement and recording points. Satellite photo source: google.maps.com (accessed on 23 June 2022).

The previously recorded wind turbine noise was filtered with a finite impulse response low pass filter in order to obtain IS only. The passband frequency was set to 20 Hz, while the stopband was 22 Hz with 90 dB attenuation using the Kaiser window design method.

2.2. Apparatus

The experiment (stimuli exposition) took place in the public address (PA) audio equipment warehouse in Krakow during audio engineering classes. The experiment location was chosen due to several factors. It was equipped with a set of industry standard JBL VTX G28 subwoofers (1.5 × 1.5 × 0.5 m each) that allowed high levels of low frequencies to be generated. In addition, the warehouse was quite big (12 × 30 m) and high (from 4 to 7 m) and was made of light walls consisting of steel beams, metal sheets and thin insulation. This was an important factor due to the potential standing waves that can be profound and uncontrolled in a hard-wall scenario. The warehouse background G- and A-weighted (according to ISO 7196:1995 and IEC 61672-1:2013 shown in Figure S1) equivalently continuous sound pressure levels (SPL) were approx. equal to 62 dBG (L_{Geq}) and 35 dBA (L_{pAeq}), respectively. During the experiment, two subwoofers were used and the participants were situated in front of the covered subwoofers at approx. 3–7 m in an area of around 15 m^2.

The following equipment was used for the sound recording:

- A DPA 4006 pre-polarized condenser, pressure microphones with windscreens in AB stereo configuration with the effective frequency range ±2 dB: 10 Hz–20 kHz, sensitivity of 40 mV/Pa and equivalent thermal noise level of 15 dBA re. 20 µPa.

A ZOOM F8n field recorder, with 8 microphone inputs of equivalent input noise of −127 dBu or less (A-weighted, +75 dB input gain, 150 Ω input), and a frequency response given by the manufacturer of 20 Hz to 60 kHz, +0.5 dB/−1 dB (192 kHz sample rate). The ZOOM F8n measurement of frequency response performed by the authors showed that the lower limit is evenly expanded to 10 Hz and only falls by −3 dB to 5 Hz. The actual lower limit without attenuation of the measured microphones is at around 3–4 Hz.

- The level calibration of stimuli playback was performed in situ using a SVAN 959 sound analyzer equipped with a G.R.A.S. 40AE microphone and SV12L microphone preamplifier. The device is of class 1 accuracy, in accordance with EN 61672-3:2014, so the monitored level error should not exceed +/− 1.1 dB.

The target level of stimuli to be played back by the subwoofer set was established based on measurements in wind farm A. The electric power of the WT is 2 MW, the recordings and the measurements were conducted at a height of 1.6 m and 250 m distance leeward. The measured SPL equaled 80.3 dBG and 46.3 dBA. The modulation depth of the recorded signal was around 4 dB and 1 Hz rate, and the signal level, as well as particularly the frequency bands, was very variable with deviations of approx. 10 dB.

The stimulus signal was amplified and equalized to achieve levels in 5–20 Hz bands as close as possible to target levels in the corresponding frequency range. The result of the level calibration is shown in Figure 2. The proper match of levels was achieved for the 10 Hz band only. For 8 Hz, the level of stimuli was around 6 dB lower, for 6.3 Hz it was around 3 dB, and for 5 Hz it was significantly lower than the target level. For these very low frequencies, the subwoofers could not produce enough energy and any more equalization caused audible harmonic distortion and an even more prominent rise of levels in 10–20 Hz frequency bands. Any further cuts in the bands over 10 Hz caused dumping of the lower frequencies. The overall L_{Geq} level of the stimuli was around 3 dB higher than that observed in the field due to the calibration issues. The resulting spectrum of stimuli is a kind of compromise between the target level of IS around wind turbines and technical limitations of the sound source.

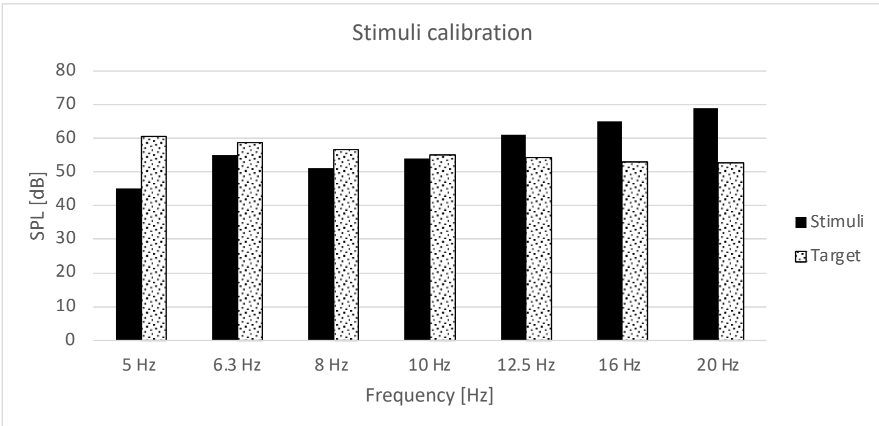


Figure 2. The target level of the wind turbine noise and the resulting stimuli after calibration.

The levels of stimuli were measured in the area where the stimuli exposure took place and were monitored all the time during the experiment.

In general, three different noise exposure conditions were used in this experiment:

- "Stimulus", i.e., recorded and filtered wind turbine noise at an approx. equivalent-continuous G-weighted SPL (L_{Geq}) and low-frequency (LF) A-weighted SPL ($L_{pA,LF}$) equal to 83 dBG and 47 dBA, respectively;
- "No stimulus", i.e., background noise at approx. 63 dBG/43 dBA;
- "Reference signal", i.e., synthesized steady LFN at approx. 78 dBG/46 dBA.

The exemplary plot of SPLs during the daily sessions is shown in Figure 3. The figure shows time slots when exposition took place with randomly applied stimuli (wind turbine IS noise), the reference signal or none. During the classes, the overall SPL (L_{Aeq}) was high but not related with stimuli or the reference signal level. It was the background noise during the experiment that was a result of outdoor urban sounds (traffic, etc.), talks between the students and teacher, and occasional audio signals generated during work with microphones and mixers. There was no intentional or artificial noise introduced in the case of background noise exposure only. As a reference signal, a set of pure tones in IS

1/3 octave bands was used. A total of 7 sine oscillators (5–20 Hz) were used to synthesize the reference signal without any AM or deviation. The reference signal level was adjusted to the same level as the stimuli. The background levels in the acoustic range were much higher during the classes, as expected, but some variations of background noise below 6 Hz were observed, so it is subject to additional statistical analysis of the results.

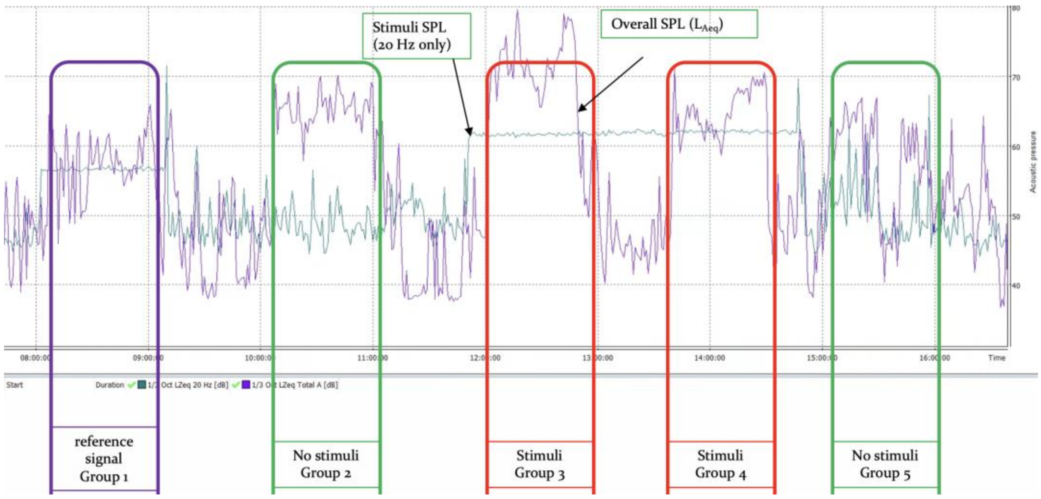


Figure 3. Level of stimuli and acoustic background monitoring during a sample day of the experiment.

2.3. Participants

The study comprised 15 seminary groups of students (129 subjects, including 74 females and 55 males), aged 21–24 years. The experiment was performed during audio engineering classes that lasted approx. 70–80 min. The number of examined student groups is the result of the availability of the experiment venue for classes and the experiment. The group size varied from 8 to 12 participants. All of the participants reported normal hearing, which is consistent with their field of study, being acoustics.

Since a between-subjects study design was applied, each group of students was asked to perform during randomly assigned noise exposure conditions, since a between-subjects study design was applied, each group of students was asked to perform a cognitive test evaluating attention, after approx. 70–80 min of audio engineering classes during randomly assigned noise exposure conditions.

Participation in the study was voluntary and there was no financial gratification for the participation. Subjects were recruited using an oral advertisement. No exclusion criteria were applied; thus, all the people who responded to the invitation could participate. The subjects certified in writing their consent to participate in the research. The study design and methods were approved by the Ethics Committee for the Research Involving Human Participants at the Adam Mickiewicz University in Poznan (Ordinance No. 15/2020/2021 adopted on 28 September 2021) and the Bioethics Committee of the Nofer Institute of Occupational Medicine of Lodz, Poland (Decision No. 4/2022 of 10 June 2022).

A number of study subjects (n = 64) were exposed to recorded and filtered wind turbine noise ("stimulus"), with the others exposed to "no stimulus" (n = 43) or to the "reference signal" (n = 22).

2.4. Procedure

The overall experiment concept is presented in Figure 4, which shows all the phases described in detail in the previous and following subsections.

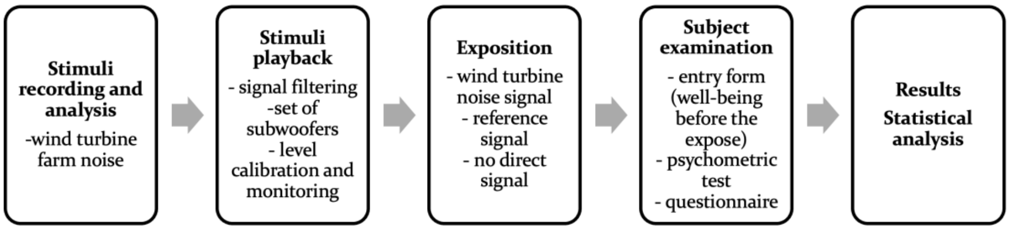


Figure 4. The experiment design.

In order to elucidate the influence of infrasound and LFN on cognitive functions, a Work under Stress Simulator (SPS) paper and pencil test was selected. This test was created as a result of the need for a test examining the impact of distractors (stressors) on the efficiency of cognitive functions, especially the system responsible for the selection of information. Attention plays such a role in our cognitive "system". Normally, it is used with a device consisting of a table with a light-permeable top, on which we place the test sheet, headphones and a remote control to control the device. During the test task (number substitution test), the subject is exposed to stimuli that make it difficult to perform it correctly. It takes 3 min to complete one task. The SPS simulator allows researchers to determine the level of fitness and the degree of concentration on a task under stress caused by disturbing stimuli (light and sound). However, in this study, the three different exposure conditions play the role of the disturbing stimuli. The test result is the number of correct answers [31].

Prior to performing the psychometric test, the study subjects were asked to fill in a so-called "initial" (pre-exposure) questionnaire developed to enable the evaluation of their well-being before classes. The aforementioned questionnaire included the following questions:

(1) How many hours did you sleep last night?
(2) Did you have any problems falling asleep?
(3) If YES, why?
(4) Was the sleep broken?
(5) Was the sleep as long as usual?
(6) Did you wake up rested?
(7) How do you feel now? (Very good/ Good/So-so/Rather bad/Bad)
(8) Do you have health problem now?
(9) If YES, then what is it? . . .

In turn, after the psychometric test, they answered a "final" (post-exposure) questionnaire concerning symptoms (feelings and complaints) subjectively related to acoustic conditions:

(1) Did you feel any additional or unusual sensation during the classes?
(2) Did you hear additional sounds?
(3) Did you feel pressure in your ears?
(4) Did you feel pressure in your head?
(5) Did you feel vibration in the room?
(6) Did you feel vibration in part of your body?
(7) Did you suffer in any way?
    (7a) Headache?
    (7b) Problems with concentration?
    (7c) Dizziness?
    (7d) Drowsiness?
    (7e) Fatigue?
    (7f) Others . . . ?

According to the post-exposure questions, any later feelings refer to questions 1–6, while ailments refer to questions 7–7f. The questionnaire was modeled on a previously developed one, which was aimed at evaluating the effects of the exposure to LFN [25].

2.5. Data Analysis—Main Hypothesis

In order to analyze the possible impact of IS/LFN on human well-being, the study subjects were divided into subgroups according to exposure conditions and gender, since it was noticed during data evaluation that there are some significant differences between males' and females' responses to the experiment. This also corresponds with the literature findings that the prevalence of noise annoyance was higher among women than in men [32–34]. In the study of Okonon et al. [32], the authors found that females showed some evidence of an association with noise annoyance and stronger evidence of association with noise sensitivity than males.

The majority of answers to the questionnaires shown in Section 2.4 were YES or NO, while only a few were given on the ordinal scale (e.g., on a 5-grade verbal rating scale). However, additionally, the total number of feelings and ailments subjectively related to exposure conditions was also determined in case of the post-exposure questionnaire. Thus, the above-mentioned answers (YES or NO) were presented as proportions with 95% confidence intervals (95% CI) in various subgroups of students. The differences between them were compared in pairs using the exact Fisher test or chi^2 test.

One-way ANOVA, or its non-parametric equivalent, i.e., the Kruskal–Wallis H test, where applicable, was used to evaluate the main effect of exposure conditions on the psychometric test results and other variables (e.g., the total number of ailments) in females and males, separately and together. On the other hand, the differences between exposure groups were compared in pairs using a post hoc Tukey's HSD test or multiple comparisons using the rank sums method in the case of non-parametric data.

On the other hand, the strength and direction of associations existing between variables were assessed using a gamma coefficient. To evaluate differences between two unmatched samples of observations on an ordinal scale (e.g., comparing the answers of men and women on a 5-grade verbal rating scale), the Mann–Whitney test was used.

The Statistica (ver. 9.1. StatSoft Inc., Tulsa, OK, USA) software package was used for statistical analysis. All tests were conducted with an assumed $p = 0.05$ significance level. However, when exploring several comparisons in pairs at the same time, to avoid the risk of mass significance, Bonferroni's method was applied, reducing the p-value considered statistically significant by dividing it with the number of possible comparisons.

2.6. Additional Analysis

For an in-depth exploration of the main problem of the paper, additional analyses were performed in order to address the influence of known issues during the experiment mentioned in the method section, such as perceived changes in exposure conditions due to the mechanical movements of the loudspeaker coil, the sensed impact of exposure conditions due to the fatigue of subjects before the exposure or the influence of background noise below 5 Hz that was not possible to control. In order to exploit that, the binary logistic multiple regression was used to study the impact of the mentioned variables on the main hypothesis results. The Nagelkerke pseudo—R^2 was applied as a measure of explained variance while the correct classification rate (CCR) was considered as a measure of fit of the logistic model. The results of the additional data analysis are presented in the Supplementary Materials.

3. Results

The subjective assessments of well-being before audio engineering classes in study subjects are presented in Table 1. There were no significant differences between subjects performing the psychometric test in various exposure conditions. Basically, with one exception, similar relations were observed when comparing answers given by females and males. It turned out that an almost two-times greater proportion of men than women woke up well rested before the classes (Table 1).

Table 1. Answers to the pre-exposure questionnaire in study subjects divided into subgroups according to exposure conditions and gender.

Answers to the Questionnaire	Exposure Conditions			Gender	
	No Stimulus (n = 43)	Reference Signal (n = 22)	Stimulus (n = 64)	Females (n = 74)	Males (n = 55)
	M ± SD				
Number of hours slept	6.4 ± 1.3	5.8 ± 1.3	6.5 ± 1.6	6.2 ± 1.5	6.6 ± 1.4
Self-assessment of well-being on 1–5 score scale	3.6 ± 0.9	3.5 ± 1.0	3.6 ± 0.9	3.5 ± 1.0	3.7 ± 0.7
	Proportion of Respondents [%] (95% CI)				
Having trouble falling asleep	18.6 (9.6–33.0)	13.6 (4.1–34.4)	29.7 (19.9–41.9)	25.7 (17.1–36.8)	20.0 (11.5–32.6)
Sleep was interrupted	37.2 (24.4–52.2)	27.3 (13.0–48.5)	25.0 (16.0–37.0)	29.7 (20.5–41.0)	29.1 (18.8–42.3)
Sleep lasted as usual	53.5 (38.9–67.5)	27.3 (13.0–48.5)	37.5 (26.7–49.8)	36.5 (26.5–47.9)	47.3 (34.7–60.2)
Woke up refreshed	44.2 (30.5–58.9)	27.3 (13.0–48.5)	42.2 (30.9–54.4)	29.7 * (20.5–41.0)	54.5 * (41.5–66.9)
Having health problems now	18.6 (9.6–33.0)	27.3 (13.0–48.5)	18.8 (11.0–30.2)	16.2 (9.4–26.5)	25.5 (15.8–38.5)

CI—confidence interval. * Significant difference between females and males (chi^2 test, $p < 0.05$).

The outcomes of the post-exposure questionnaire are given in Table 2. There were no significant differences in answers to the questions between students exposed to the stimulus and reference signal. However, only some symptoms were more frequently reported by subjects exposed to the stimulus compared to those without any stimulus. Such relations were noted in the case of feeling the pressure changes in someone's head and experiences of physical or mental discomfort, as well as the perception of any changes in exposure conditions (exact Fisher test, $p < 0.05/3$).

Furthermore, there were significant differences between females and males. Men more often than women reported pressure changes in their ears and felt vibrations in the room, while females generally more frequently sensed the impact of exposure conditions and complained of headache, sleepiness and fatigue ($p < 0.5/3$). Moreover, the total number of ailments related to exposure conditions was significantly greater in females than in males (Table 2). However, no significant impact of exposure conditions was observed when analyzing the proportions of answers to the post-exposure questionnaire in men and women separately ($p > 0.05/3$).

The analysis, using the gamma coefficient, revealed a significant relationship between pre-exposure well-being and reported post-exposure complaints(Table 3). In particular, it has been shown that the greater the number of hours being slept or the better well-being before the classes, the smaller the number of reported post-exposure ailments. Furthermore, subjects with health problems suffered from a greater number of ailments subjectively related to exposure conditions, while those with problems falling asleep (or woke up rested) reported a greater number of feelings due to exposure conditions compared to others (Table 3).

Table 2. Answers to the post-exposure questionnaire in study subjects divided into subgroups according to exposure conditions and gender.

Answers to the Questionnaire	**Exposure Conditions**			**Gender**	
	No Stimulus (n = 43)	**Reference Signal (n = 22)**	**Stimulus (n = 64)**	**Females (n = 74)**	**Males (n =55)**
	Proportion of Respondents [%] (95% CI)				
Felt an additional signal, stimulus or other unusual sensation during the classes	11.6 (4.7–25.1)	9.1 (1.5–29.3)	26.6 (17.3–38.6)	18.9 (11.6–29.5)	18.2 (10.1–30.6)
Heard noise, a hum or sound other than the typical background acoustics	39.5 (26.4–54.5)	31.8 (16.3–52.9)	42.2 (30.9–54.4)	44.6 (33.8–55.9)	32.7 (21.8–46.0)
Felt pressure changes in the ears	25.6 (14.9–40.4)	22.7 (9.9–44.0)	29.7 (19.9–41.9)	20.3 ** (12.6–31.0)	36.4 ** (24.9–49.6)
Felt pressure changes in the head	9.3 * (3.2–22.3)	9.1 (1.5–29.3)	29.7 * (19.9–41.9)	17.6 10.5–28.0)	21.8 (12.9–34.6)
Felt vibrations in the room	7.0 (1.8–19.5)	22.7 (9.9–44.0)	21.9 (13.4–33.6)	10.8 ** (5.4–20.2)	25.5 ** (15.8–38.5)
Felt vibrations in the body	9.3 (3.2–22.3)	22.7 (9.9–44.0)	21.9 (13.4–33.6)	17.6 (10.5–28.0)	18.2 (10.1–30.6)
Experienced physical or mental discomfort	14.0 * (6.3–27.8)	27.3 (13.0–48.5)	34.4 * (23.9–46.7)	25.7 (17.1–36.8)	27.3 (17.3–40.4)
Headache	18.6 (9.6–33.0)	4.5 (−0.7–23.8)	17.2 (9.8–28.5)	21.6 ** (13.7–32.4)	7.3 ** (2.5–17.9)
Concentration problem	23.3 (13.1–38.0)	27.3 (13.0–48.5)	39.1 (28.1–51.3)	37.8 (27.7–49.3)	23.6 (14.3–36.5)
Dizziness	2.3 (0.0–13.4)	9.1 (1.5–29.3)	6.3 (2.1–15.6)	2.7 (0.2–10.0)	9.1 (3.6–20.1)
Sleepiness	30.2 (18.6–45.2)	36.4 (19.8–57.2)	35.9 (25.3–48.2)	41.9 ** (31.3–53.3)	23.6 ** (14.3–36.5)
Tiredness	44.2 (30.5–58.9)	36.4 (19.8–57.2)	39.1 (28.1–51.3)	54.1 ** 42.8–64.9)	21.8 ** (12.9–34.6)
Perceived some changes in exposure conditions	23.3 * (13.1–38.0)	31.8 (16.3–52.9)	48.4 * (36.7–60.4)	35.1 (25.3–46.5)	40.0 (28.1–53.2)
Sensed the impact of some exposure conditions	41.9 (28.4–56.7)	40.9 (23.3–61.3)	48.4 (36.7–60.4)	52.7 ** (41.5–63.6)	34.5 ** (23.4–47.8)
	M ± SD				
The total number of feelings subjectively related to exposure conditions	0.8 ± 1.1	1.0 ± 1.6	1.4 ± 1.5	1.1 ± 1.3	1.2 ± 1.5
The total number of ailments subjectively related to exposure conditions	1.4 ± 1.6	1.7 ± 2.1	2.0 ± 1.9	2.1 ± 1.9 ***	1.3 ± 1.8 ***

CI—confidence interval; M—mean; SD—standard deviation. * Significant differences between groups of students non-exposed and exposed to stimulus (the exact Fisher test, $p < 0.05/3$); ** Significant differences between females and males (chi^2 test, $p < 0.05$). *** Significant difference between females and males (U-Mann–Whitney test, $p < 0.05$).

Table 3. Relationships between results of pre- and post-exposure questionnaires assessed using a gamma coefficient. Data concern all study subjects.

Answers to the Questionnaire		Total Number of	
		Feelings	Ailments
		γ coefficient	
1	Number of hours slept	−0.019	−0.226 *
2	Problems with falling asleep	0.423 *	0.301 *
4	Interrupted sleep	0.114	0.200
5	Sleep lasted as long as usual	0.229 *	−0.161
6	Woke up rested	0.218 *	−0.399 *
7	Self-assessment of well-being	−0.173	−0.500 *
8	Having health problems	0.006	0.435 *
	Tired before classes	0.091	0.408 *

* Significant values of the γ coefficients ($p < 0.05$).

No significant associations between the performance level of the psychometric test and the self-assessment of students' well-being before classes were noted. However, there was a weak but statistically significant positive relationship between gender and performance level of the psychometric test (γ coefficient = 0.212, $p < 0.05$). Therefore, the differences in the psychometric test performance due to various exposure conditions were analyzed both in females and males, separately and together. The results in Figure 5 show that no significant effect of exposure conditions was noted in females (ANOVA, $F(2, 70) = 0.125$ $p = 0.883$) or males (ANOVA, $F(2, 50) = 1.246$ $p = 0.296$). A similar outcome was obtained when analyzing the impact of exposure conditions in all study subjects (ANOVA, $F(2, 123) = 0.403$ $p = 0.669$).

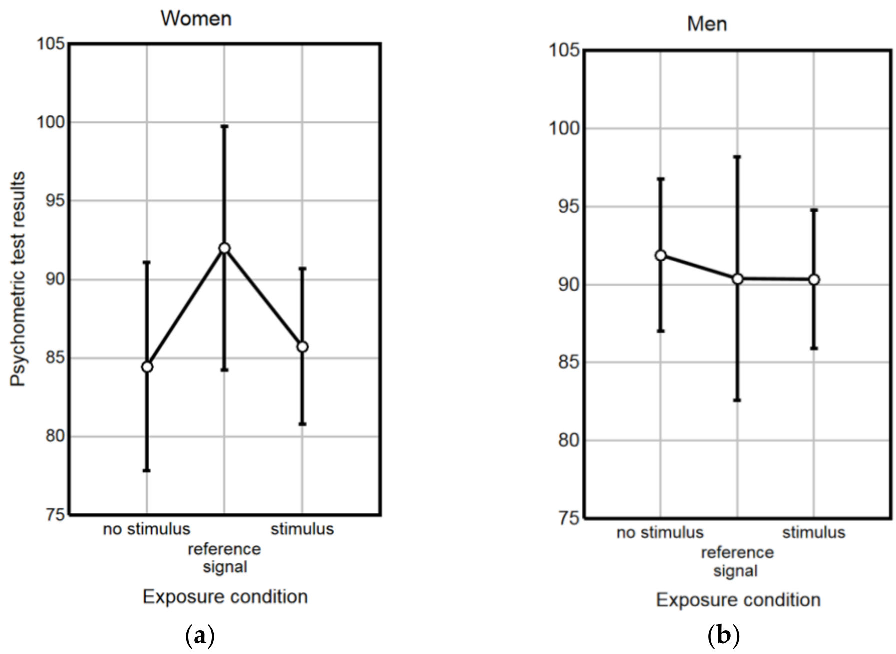
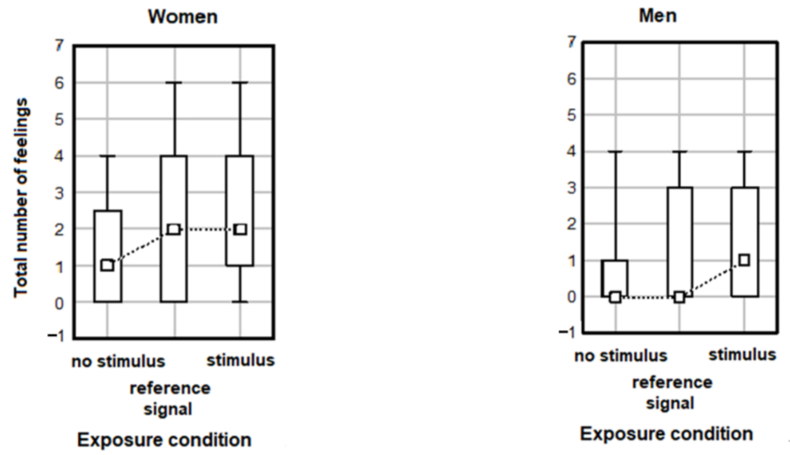


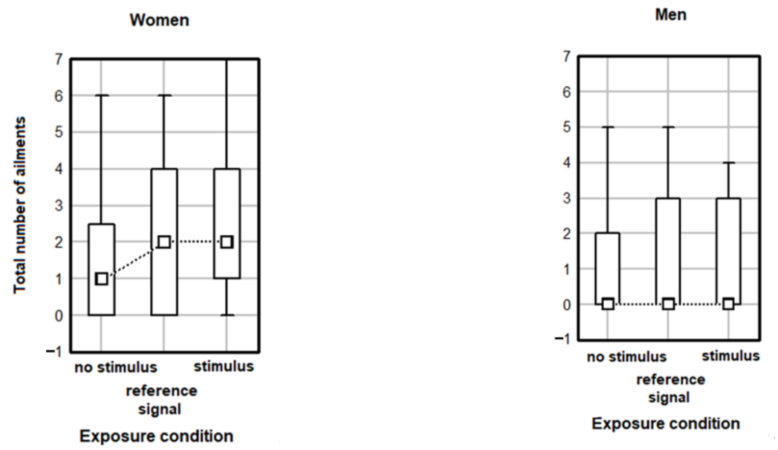
Figure 5. Results of the work under stress simulator test in various exposure conditions among (**a**) female and (**b**) male students. Data are given as mean values with 95% confidence intervals.

The gender-related analysis was also performed for the total number of feelings and the total number of ailments in relation to exposure conditions. The results show no significant effect of exposure conditions for females (Kruskal–Wallis test $H(2, N = 74) = 3.91$ $p = 0.142$) or males (Kruskal–Wallis test $H(2, N = 55) = 1.545$ $p = 0.462$), considering the perception of stimuli (Figure 6) and no significant effect of exposure conditions was noted in females (Kruskal–Wallis test H(2, N = 74) = 2.442 p = 0.259) or males (Kruskal–Wallis test H(2, N = 55) = 0.931 p = 0.628) in regard to the total number of ailments (Figure 7). Similar conclusions was drawn when analyzing the impact of exposure conditions on the total number of feelings (Kruskal–Wallis test H(2, N = 129) = 5.251 p = 0.072) and ailments (Kruskal–Wallis test H(2, N = 129) = 2.276 p =0.320) in females and males together.



(a) (b)

Figure 6. Total numbers of post-exposure feelings reported in various exposure conditions by (**a**) female and (**b**) male students. Data are given as median values with 5th, 25th, 75th and 95th percentiles.



(a) (b)

Figure 7. Total numbers of post-exposure ailments reported in various exposure conditions by (**a**) female and (**b**) male students. Data are given as median values with 5th, 25th, 75th and 95th percentiles.

4. Discussion

In this paper, all stages of the experiment were described, starting from the recording of the IS and LFN generated by wind turbines and their playback using a set of PA grade subwoofers and ending with a discussion of the results. The recording of the infrasound is not a complex procedure, but it requires careful study of the recording equipment below the 20 Hz range as most of the conventional audio recording devices very often have a built-in HPF (high pass filter). On the other hand, IS playback is a very difficult process. In order to achieve proper levels in the IS range, very high loudspeaker membrane amplitudes are required. Most of the conventional audio equipment is not efficient below 20 Hz, and increasing these bands causes prominent harmonic distortion or mechanical noise accompanying IS playback. Hence, the exact recreation of wind turbine IS was not possible for the selected bands below 10 Hz. Attempts at the exact matching of the stimuli to the wind turbine signals resulted in rising levels of higher harmonics due to the distortion. Therefore, the frequencies at around 20 Hz were much higher during playback than expected and, as a result, caused more frequent stimuli discrimination than predicted. In particular, the statistical analysis of the results showed that this phenomenon did not disturb the credibility of the results. Another potential technical obstacle with IS and LFN exposition is the standing wave issue. The length of low frequencies very often corresponds with the building, room or corridor dimensions, and high local resonances or antiresonances are observed. This problem was solved by conducting the experiment in a lightweight building construction. Another potential solution could be working outside the building, but this would cause some other technical problems as well.

However, the conducted experiment has several weaknesses as well. Firstly, between-subjects study design was selected with an unequal number of participants. Secondly, the inference was based on the results of one psychological test and two questionnaires. Thirdly, individual sensitivity to noise was not taken into account and, fourthly, basically no exclusion criteria of participants were used. Meanwhile, in the case of the between-subjects study design: different people test each condition, so that each person is only exposed to a single user interface. On the other hand, in the within-subjects (or repeated-measures) study design: the same person tests all the conditions (i.e., all the user interfaces). The between-groups designs reduce learning effects; repeated-measures designs require fewer participants and minimize the random noise. On the other hand, increasing the number of people surveyed may make it possible to recognize smaller differences between the surveyed groups as statistically significant. In turn, the unification of group sizes may lead to homogeneous variances in groups, which would enable statistical analyses that are unavailable at the present stage of research, e.g., the analysis of covariance (ANCOVA).

Nevertheless, generally speaking, the outcomes of the present study do not contradict the results of previous research. However, further studies are needed before firm conclusions can be formulated concerning the health impacts of wind turbine infrasound, taking into account standardized and more appropriate psychological methods, such as more demanding cognitive tests.

5. Conclusions

In the current work, the influence of acoustic conditions and gender on the level of human mental performance, as well as that of the feelings and ailments associated with the exposure conditions, were analyzed.

The main, but not straightforward, conclusion of the work is that there were no statistically significant differences in response rates between subjects exposed to infrasound of WT origin and steady IS without AM modulation. However, small but significance differences were visible between people exposed to WT infrasound and people without exposure. Generally, the latter subgroup less frequently reported feeling pressure changes in the head, experience of physical or mental discomfort and the perception of any changes in exposure conditions. The second output should be especially robust due to its potential prominence; therefore, several other factors have been carefully examined.

There were also significant differences between females and males. Generally, a greater proportion of males perceived changes due to exposure conditions, while females more often felt worse after classes. However, no significant impact of exposure conditions was observed when analyzing the proportions of answers to the post-exposure questionnaire in men and women separately ($p > 0.05/3$).

There were no significant differences in the self-assessment of well-being before classes between subjects performing the psychometric test in various exposure conditions. Basically, with one exception, neither exposure conditions nor gender had a significant impact on the self-assessment of subjects' well-being before classes. In addition, there were no significant associations between the performance level of the psychometric test and the self-assessment of students' well-being before classes. On the other hand, a significant gamma coefficient between pre-exposure well-being and reported post-exposure complaints has been found. Generally, subjects well rested before classes felt better after their end. Additionally, no significant differences in performance levels of the work under stress simulator test in various exposure conditions were found in males and females analyzed separately. Similar results were obtained when analyzing the total number of feelings and ailments subjectively related to exposure conditions during classes.

Returning to the main conclusion and the expressed doubts, on the basis of the above additional factors and results analyses shown in the Supplementary Materials (Tables S1–S3), we conclude that it is much more probable that the obtained influence of WT IS on subjects' well-being is a result of: unintentional perception of the stimuli, presence of IS background below 5 Hz or the tendency of a specific group (in this case females) to report negative well-being after the classes if they were tired before the classes.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ijerph20032223/s1, Table S1: Relationships between gender and outcomes of the post-exposure questionnaire assessed using a gamma coefficient. Data concern all study subjects; Table S2: Association between PC (any perceived changes in exposure conditions) or SI (the sensed impact of exposure conditions on well-being) (dependent binary variable) and gender, fatigue and type of noise conditions (independent variables) tested using logistic regression; Table S3: A gamma coefficient between the noise parameters and the outcomes of the post-exposure questionnaire. Figure S1: Nominal G-, A-, C- and Z-weighting characteristics according to ISO 7196:1995 and IEC 61672-1:2013.

Author Contributions: Conceptualization, P.M., M.P.-Ł. and A.P.; methodology, P.M., M.P.-Ł. and A.P.; validation, M.K., P.P., B.S., A.P. and A.D.; investigation, P.M., P.P., T.W., M.K., B.S. and D.M.; resources, M.K. and B.S.; writing—original draft preparation, P.M. and M.P.-Ł.; writing—review and editing, M.K., P.P. and B.S.; visualization, P.M., M.P.-Ł. and A.D.; project administration, P.P., T.W. and A.P.; funding acquisition, A.P. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee for the Research Involving Human Participants at the Adam Mickiewicz University in Poznan (Ordinance No. 15/2020/2021 adopted on 28 September 2021) and the Bioethics Committee of the Nofer Institute of Occupational Medicine of Lodz, Poland (Decision No. 4/2022 of 10 June 2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the privacy of the participants.

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

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Infrasound of a Wind Turbine Reanalyzed as Power Spectrum and Power Spectral Density

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Comment on Pilger and Ceranna [1]: The influence of periodic wind turbine noise on infrasound array measurements (JSV, Vol. 388, pp. 188–200, 2017)

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The infrasound levels due to the blade-tower interaction generated by a wind turbine in the publication by Pilger and Ceranna (JSV, Vol. 388, pp. 188–200, 2017) have to be corrected to be interpreted as sound pressure level. Also, the electrical power of the wind turbine should be corrected for the high wind case to 660 kW. We provide a reanalysis of the measured data with a power spectrum showing levels for the low-frequency signal of the wind turbine about 34 dB below the original work. All measured levels at a distance of 200 m from the wind turbine's infrasound signal are well below the hearing threshold.

Keywords: Parseval's Theorem, Low-frequency sound, Noise bandwidth, Discrete Fourier transform, Sound pressure level

1. Introduction

The noise of wind turbines travels across property lines and is audible in the neighborhood. Despite comprehensive research on wind turbine noise [2–6], the debate about potential severe adverse health effects continues. Most of the wind turbine noise is in the audible frequency range. Our ability to sense moderate levels of low frequencies fades away below 20 Hz. However, the rotor blade passing the tower generates a characteristic pressure signal with dominant harmonic frequencies below 20 Hz, in the so-called infrasound range [7]. In principle, such an infrasound signal could be sensed if the levels are high enough. In recent years, the debate in Germany rose and had controversy on the level of such infrasound emitted by wind turbines. In our view, this debate is mainly rooted in a misinterpretation of the infrasound signal of a wind turbine measured by Pilger and Ceranna [1].

The measured pressure in the vicinity of a running wind turbine at ground level mainly consists of the random signal due to the wind and the turbine's periodic signal. Already at a wind speed of a few meters per second, the dynamic pressure is in the order of several Pascals. The unsteadiness of the wind causes a corresponding fluctuating pressure signal. The rotor blade of a wind turbine moves freely through the air until it approaches the tower. If the blade passes by the tower, the pressure field changes smoothly due to the interaction by the subsonic flow. This temporal change of the pressure field is measurable in the close neighborhood of a wind turbine. The rotation speed and number of blades set the periodicity.

2. Results

2.1. Inconsistency in published data in original work

Pilger and Ceranna [1] measured the outdoor pressure signal nearby a wind turbine and presented a spectrum with a short excerpt of the time series in their work. The amplitudes of their spectrum are the basis for their discussion and have been referenced by others. It is unclear how they scaled their spectrum and how the reported values of sound pressure level (SPL) should be interpreted.

We begin with an order of magnitude estimate under the assumption that the excerpt of the time series in their upper figure 4 is a representative excerpt for the spectrum shown below for the high wind conditions. Impulsive peaks repeat with a frequency of about 1.3 Hz, consistent with the 26 rounds per minute of the high wind conditions. A conservative estimate of the root-mean-square pressure based on the peak-to-peak value of their figure 4 and a sinusoidal function yields about 0.07 Pa. This corresponds to a sound pressure level of about 71 dB by using the reference pressure of 2×10^{-5} Pa. The time-series signal was filtered with a 0.5 Hz high-pass filter. For frequencies above the filter frequency, the spectrum in the lower part of the figure has distinct peaks with amplitudes above 80 dB. The interpretation as a power spectrum – as the label and units of the ordinate might suggest – is not consistent with Parseval's Theorem. The levels of the harmonics are higher than the estimated sound pressure level. Pilger and Ceranna [1] do not supply sufficient details in their work to identify the scaling of the presented spectrum unambiguously. The inconsistency and the incomplete description of the data analysis have motivated us to reanalyze the publicly available time-series data[1] [8].

2.2. Power spectral density and power spectrum

A Fourier transformation allows us to present time series data in the frequency domain. For the representation of the power as a function of frequency, a commonly used quantity in physics is the *power spectral density* (PSD). For random signals with peaks broader than the bandwidth, this quantity is continuous over the frequency and independent of the analysis bandwidth [9]. However, the PSD diverges at the peaks of discrete frequencies. For a sinusoidal signal, the PSD is a delta function. By integration over frequency, one obtains the *power spectrum* (PS), which is finite at the peak of a sinusoidal signal. However, for a random signal, the level of a PS decreases with the number of observed samples and is thus dependent on the windowing.

We have analyzed the data based on overlapped segmented averaging of modified periodograms [10] to obtain a spectrum with low variance. The long time series is analyzed by weighting segment by segment with a window function, performing a discrete Fourier transform, and averaging the squared pressure spectra. The discrete analysis has a finite bandwidth, depending on the sampling frequency, window length, and weighting function. Before the windowing, the subtraction of an average trend by linear

[1] To retrieve the data, for example, for the high wind condition:
http://eida.bgr.de/fdsnws/dataselect/1/query?station=HUF03&channel=HDF&starttime=2004-07-10T12:40:00&endtime=2004-07-10T13:10:00
with the corresponding metadata:
http://eida.bgr.de/fdsnws/station/1/query?station=HUF03&channel=HDF&starttime=2004-07-10T12:40:00&endtime=2004-07-10T13:10:00&level=response
The data can be converted to ascii by using mseed2ascii
https://github.com/iris-edu/mseed2ascii (accessed January 28, 2021).

regression removes the offset and possible leakage in adjacent frequency bands. For a discrete PSD the PS is obtained by integrating over each frequency bin separately. For simplicity, the amplitude is taken to be constant within the bin. Under this assumption, the integration results in power spectrum value times bin width. The spacing along the frequency axis, the bin width is set by the frequency resolution f_{res}, which is related to the sampling frequency f_s, and the window length N by $f_{res} = f_s/N$. Finally, Parseval's theorem states that the power of a measured signal is equal to the sum of all components of the PS. If a window was applied, the components have to be divided by the normalized effective noise bandwidth [11] before the summation.

For the reanalysis, the flat-top window HFT70 with a length of $N = 2^{14} = 16384$ samples and an overlap of 72.2 % was chosen, which has a high amplitude accuracy [10]. The original recording sampling frequency was f_s = 100 Hz [1] and was kept unchanged. This yields a bin width of f_{res} = 0.0061 Hz. In Fig. 1, the PS and PSD are plotted next to each other. We use $p_{ref} = 2 \times 10^{-5}$ Pa and the frequency of 1 Hz as references for the decibel scaling of PS and PSD. The standard definition of sound-pressure level as $SPL = 10 \cdot \log10(p_{RMS}^2/p_{ref}^2)$ and no frequency weighting was employed.

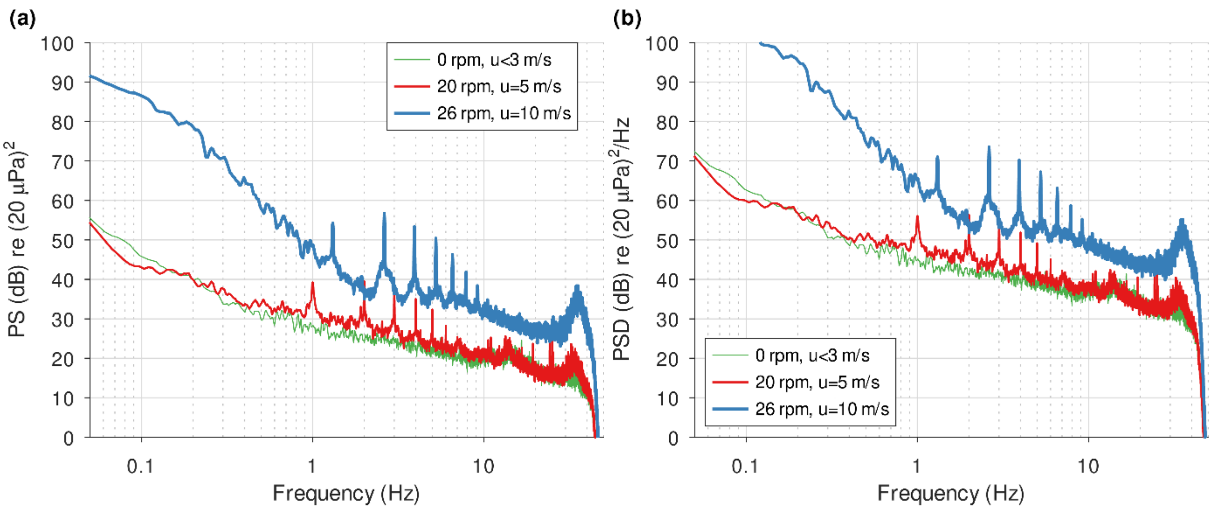

Figure 1: The power spectrum (PS, a) and the power spectral density (PSD, b) of pressure measurements recorded at a distance of about 200 m to a wind turbine. The PS and PSD differ only by a constant offset of 16.8 dB. The raw data originate from Pilger and Ceranna [1]. The turbine was turning with low rounds per minute (20 rpm, u = 5 m/s) or high (26 rpm, u = 10 m/s) or standing still (0 rpm, u < 3 m/s).

The noise bandwidth defines the constant scaling factor between PS and PSD [10], which is for this analysis 16.8 dB. This factor is set by the ratio f_s/N and the normalized effective noise bandwidth of the used window [10], here 3.41. The spectra resemble in shape the original publication but have an offset of approximately -34 dB for the PS and -17 dB for the PSD with respect to the original publication.

2.3. Scaling of the spectra

A good agreement with the spectra presented by Pilger and Ceranna [1] in their figure 4 was achieved with a Hanning window with length $N = 8192$, an overlap of 50 %, and by showing the PSD times an estimated constant factor of about 50 by comparison with the original figure. Consistent with our analysis, this factor results in about 17 dB higher values than the PSD. The actual correction factor might differ by about 1 dB due to the graphical comparison.

Both spectra depend on the window length because the signal contains random and sinusoidal components. Fig. 2 depicts the first prominent peak region at about 1.3 Hz of the high wind spectrum.

The noise floor of the PS drops by about 3 dB for each doubling of the window length. The spacing on the frequency axis scales for the given sampling frequency inversely with the window length *N*. The width of the peak decreases with a longer window length while the amplitude is almost unaffected. On the other hand, the PSD provides an estimate of the noise floor, but the peak height depends on the window length. As the wind turbine generates a signal with small but finite variability, the peak has a finite width.

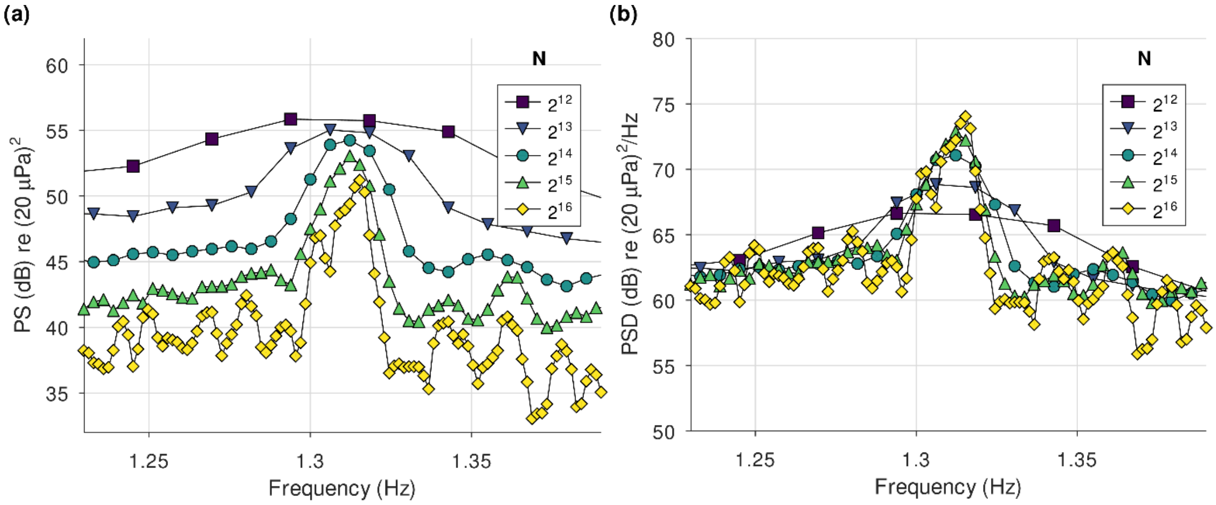

Figure 2: The power spectrum (PS, a) and the power spectral density (PSD, b) of Fig. 1 analyzed with different window lengths with 4096 to 65536 samples, covering the range from 0.0015 to 0.024 Hz for the bin width. The noise floor of the PS drops by about 3 dB for each doubling of the window length and is relatively unaffected at the peak. Contrary, the PSD provides an estimate of the noise floor, but the peak height depends on the window length. The raw data originate from Pilger and Ceranna [1].

3. Discussion

3.1. Amplitudes compared to hearing threshold

Today, we know more about how the pressure pulse due to the blade passing the tower is generated [7,12,13]. The key parameters are determined by the geometry of the blade and the tower in the configuration of the shortest distance. A common way to characterize a stationary signal is a spectrum of third octaves (Fig. 3). Published data of human hearing threshold at low frequencies [14] and the ISO 226 [15] provide estimates of the audibility of a signal at these low frequencies. Although the thresholds are generally based on sinusoidal tones, which differ to some degree from the measured signal, the levels are more than 20 dB below and, by this, clearly below the threshold's reference values. Above about 30 Hz the measured level is around the threshold, which is beyond the frequency range of the infrasound signal and possibly related to some other source than due to wind or the wind turbine's rotor blade passing the tower.

As a conservative upper bound, Fig. 3 provides the summing of the levels within the peaks of the harmonics additionally. For the high wind conditions, the sum around the fundamental and the seven distinct harmonics yields 63.1 dB, which is again well below the threshold of hearing in the corresponding frequency range. This is consistent with our conservative upper bound estimate of 71 dB for the short time series of the figure 4 of the original publication [1]. Walking causes similar pressure amplitudes by moving the head up and down by about a centimeter [16], as the pressure changes with height multiplied by density and gravitational constant. The equivalent upper bound estimate for the medium wind conditions of 46.3 dB is substantially lower.

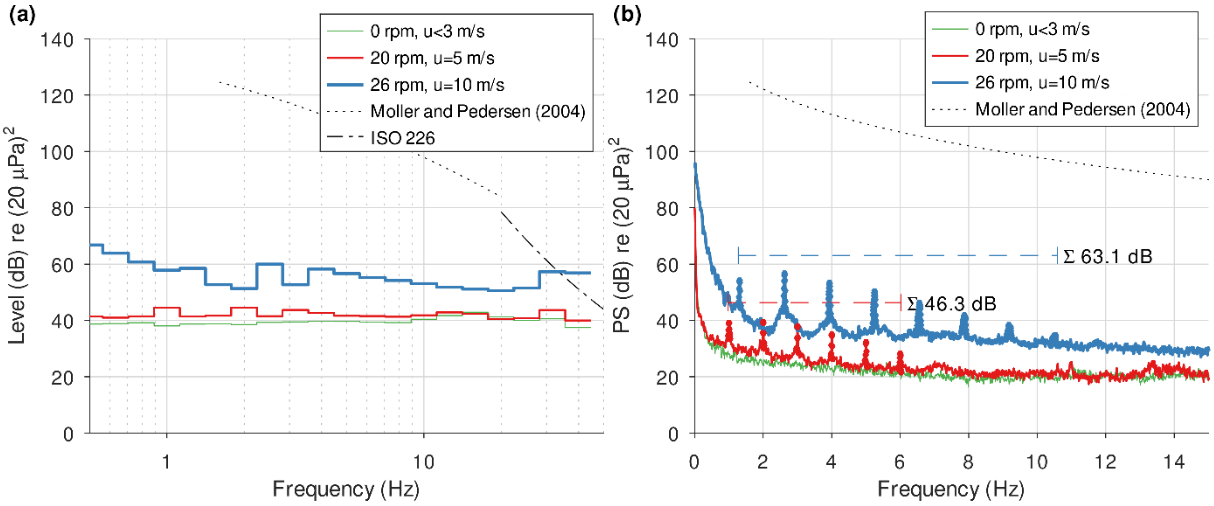

Figure 3: The sound pressure level analyzed in third octaves (a) and as power spectrum (b) in comparison to thresholds of hearing at low [14] and regular [15] frequencies. As integral value for the periodic signal, the levels in the vicinity of the peaks (marked by dots) are summed, and the integral value is indicated with the corresponding dashed line. The raw data originate from Pilger and Ceranna [1].

3.2. Electrical power of wind turbine

Additionally, we have reanalyzed the data at the neighboring stations using our approach and identified a similar decay with distance for the high wind conditions as in the work by Pilger and Ceranna [1]. This is in line with a constant offset independent of the measured signal.

Furthermore, it should be mentioned that the investigated wind turbine Vestas V47 has two electrical generators. One with 200 kW electrical power, which operates if the turbine runs at 20 rpm. In the mode with 26 rpm, a generator with 660 kW electrical power is in use. In the work by Pilger and Ceranna [1] only a value of 200 kW is reported. We suspect that the extrapolated values for higher electrical power in their figures 7 and 8 should be divided by the factor 3.3, which corresponds to subtracting 5.2 dB as an additional correction.

4. Conclusion

To sum up, the infrasound levels due to the blade-tower interaction generated by a wind turbine in the publication by Pilger and Ceranna [1] have to be corrected to be interpreted as sound pressure level. Also, the electrical power of the wind turbine should be corrected for the high wind case to 660 kW. We provide a reanalysis of the measured data with a power spectrum showing levels for the low-frequency signal of the wind turbine about 34 dB below the original work. All measured levels at a distance of 200 m from the wind turbine's infrasound signal are well below the hearing threshold.

5. Acknowledgment

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Wind turbine infrasound: Phenomenology and effect on people

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1. Introduction

Global efforts to improve sustainability have led to the rapid growth in the use of renewable energy sources such as wind energy (Deshmukh et al., 2019). This, in turn, has led to increasing numbers of wind turbines near residences and increasing exposure of the occupants to wind turbine infrasound. There are strongly partisan and contradictory findings on whether this poses a health risk. There are those who believe that since infrasound cannot be heard, it cannot do any damage. However, there is growing international evidence that it annoys some people and that this may lead to long-term health problems. This work provides an interpretive review of the multi-disciplinary research in the fields of acoustic theory, wind turbine noise, structural coupling with infrasound and the role of the central nervous system (CNS) in the human experience (Fig. 1). It provides a new perspective on the way in which wind turbine infrasound interacts with dwellings based on the fundamental properties of the sound waves. It also provides an explanation for why a small proportion of residents have a strong adverse reaction to the persistent, episodic infrasound and proposes a simple mitigation strategy. In doing so, it advances the understanding of wind as an important source of renewable energy.

Airborne sound is a sinusoidal variation in pressure that travels as a longitudinal wave through the air with a particular frequency, wavelength and amplitude. Amplitude is an objective measure of the sound pressure level (SPL) and 'loudness' is the subjective perception of the sound by the ear. The amplitude is extremely small; the average sound from a television has a pressure variation of 0.02 Pa or 20 millionths of the ambient pressure of 101.3 kPa (Le Pichon, Blanc and Hauchecorne, 2010). Perfect hearing is defined as the ability to hear airborne sounds with frequencies ranging from 20 Hz to 20,000 Hz, which corresponds to wavelengths of approximately 17 m to 17 mm respectively. The ear is particularly sensitive to sounds above 100 Hz, so early sound research focused on sounds at the higher end of the frequency spectrum and their associated effect on hearing loss. Sound below 100 to 250 Hz is called low frequency noise (LFN) and sound below about 20 Hz is called infrasound (Baliatsas et al. 2016; Mühlhans, 2017). The latter is the focus of this research. There are both natural and anthropogenic sources of infrasound. Natural sources include the eruption of volcanoes, sound produced by large animals (such as whales, elephants and rhinoceroses), thunder, avalanches and ocean waves. Anthropogenic sources include explosions, trains, submarines, machinery (such as compressors, motors and wind turbines) and the vibration of large structures such as bridges.

Infrasound has several unique properties that can be broadly categorised as, firstly, phenomenological properties and, secondly, properties relating to its effect on people.

Audible sound becomes uniformly softer with distance, losing energy to the atmosphere and obstacles and dispersing its energy as it expands to larger volumes. This is not quite the case with infrasound, which can get louder over certain distances. Because it is a plane wave, rather than a spherical wave, centred on the source, it does not suffer the geometrical effects of being spread over a volume that increases as the square of the distance. Consequently, the rubric of sound pressure level decreasing with inverse of the square of the distance is approximately true for audible sound but is not true for infrasound. Infrasound has very long wavelengths that do not interact with small objects, and it suffers very little diminution over distance. For example, 1 Hz sound is

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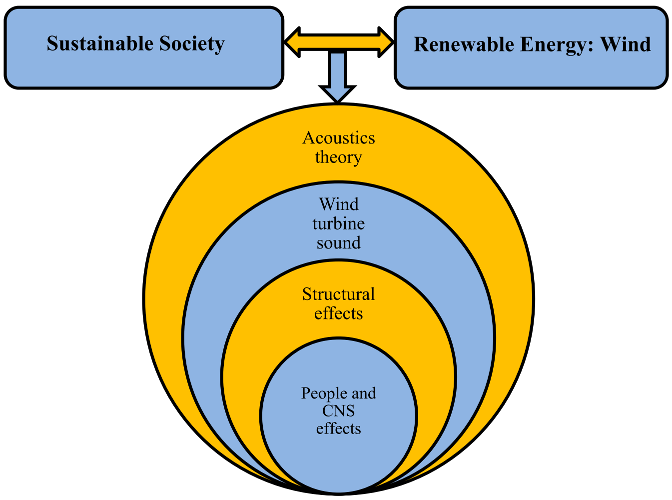

Fig. 1. Research framework: an interpretive inter-disciplinary review on wind energy as an important aspect of a sustainable society.

experimentally measured to be absorbed at 0.003 dB/100 km compared with 100 Hz sound which is absorbed at 30 dB/100 km (McComas et al., 2018). The eruption of Mount Etna in 2016 is a commonly cited example of the persistence of infrasound over long distances; it was detected 1, 200 km away with a sound pressure level that was 20% of its value at 5 km away (Bedard and Georges, 2000; Marchetti et al., 2019).

Lightweight structures are capable of responding to infrasound because the natural frequency of vibration of their elements can approach an infrasound frequency (Granzotto, Di Bella, and Piana, 2020). Its energy can therefore be transduced into sound at harmonics of the dominant infrasound frequencies and can also produce parasitic vibrations in coupled structures. Vardaxis, Bard and Persson Waye (2018) note that laboratory tests on sound transmission through building elements are not as good as field tests because they do not capture the interaction of the whole building structure in sound propagation. There is an added difficulty in studying the behaviour of infrasound, namely that most standard microphones are not capable of detecting sound frequencies below about 20 Hz, so micro-barometers must be used (CCA, 2015). The transmission of infrasound over large distances is well known and there is a global monitoring system (IMS) which consists of a network of 60 stations using micro-barometer arrays to detect explosions as part of the Comprehensive Nuclear-Test Ban Treaty (CTBT) (Bedard and Georges, 2000; Sutherland and Bass 2004; Le Pichon, Blanc and Hauchecorne, 2010). Another problem is that sound monitoring equipment commonly uses an 'A-rating' process that emphasizes the frequencies to which the human ear is most sensitive. This results in over-weighting 1,000 to 7,000 Hz sound, under-weighting 20 to 1,000 Hz sound and completely filtering out anything below 20 Hz. Despite this, A-rating is still commonly used to measure environmental sound and is the basis for dismissing claims of the presence of infrasound (Boretti, Ordys and Al Zubaidy, 2018).

Reports on the effects of infrasound on people are contradictory, and, in the case of wind turbines, have produced strong partisans. This disagreement is only possible because there is no clear and consistent explanation of the data. This is the second focus in this research. The ear is less sensitive to infrasound than it is to higher frequencies and many researchers believe that 'if the sound cannot be heard, it cannot be harmful' [Zagubién and Wolniewicz, 2020]. If this logic were correct, then by analogy infrared light would not be harmful to humans because it is not visible. In fact, infrasound is audible providing it is sufficiently loud (at a high enough sound pressure level) and it can also be sensed by the vestibular system and by cells in the skin as a vibration (CCA, 2015; Møller and Pedersen, 2004; Baliatsas et al., 2016; Mühlhans, 2017). Magnetic resonance imaging (MRI) shows activity in the auditory cortex of people exposed to 8 Hz infrasound at a loudness of 20 phon (Baeza Moyano and Gonzalez Lezcano, 2022; Boretti, Ordys and Al Zubaidy, 2018). There are many reports of infrasound causing physiological and psychological harm to people. Mühlhans (2017) provides a very comprehensive review that debunks many common myths about infrasound. The rapid expansion of wind turbine installations has raised concern about the potential health risks to nearby residents (Deshmukh et al., 2019) and the Council of Canadian Academies undertook a comprehensive review of this area (CCA, 2015). The findings of this report are:

- The sound signature from wind turbines is complex; it covers a wide range of frequencies (including infrasound), the outdoor SPLs vary depending on distance, wind speed and wind direction and amplitude modulation can result in low frequency 'swishing' or 'thumping' noises.
- There is evidence that exposure to wind turbine noise causes annoyance. This may be influenced by other factors such as attitude towards wind turbines, economic aspects and visual impacts. Evidence suggests that the infrasound and LFN components of the sound are the most likely cause of long-term annoyance.
- There is limited evidence that exposure to wind turbine noise causes sleep disturbance.
- Exposure to wind turbine noise does not appear to cause hearing loss, stress or other health effects such as tinnitus, vertigo, nausea, cardiovascular diseases, diabetes, etc. It is unclear whether these could be caused by pure annoyance.
- Epidemiological studies have limitations such as inadequate measurements, bias, poor controls and too short an exposure to the sound.

More recent work has confirmed many of these findings. The sound signature from wind turbines is discussed in Section 3.

van Kamp and van den Berg (2018, 2021) provide a detailed review of the literature on the effect of LFN and infrasound from wind turbines on the health of nearby residents, including annoyance, sleep disturbance, cardiovascular disease, metabolic effects, and mental and cognitive impacts. They also consider non-acoustic factors such as the visual impact of wind turbines, people's perceptions and attitudes about wind turbines and their involvement in planning wind turbine farms. They show that annoyance is the most common effect and that the louder the noise, the greater the annoyance. The annoyance may also be increased by visual impacts and by rhythmic pulses on the dwellings. The annoyance itself may be the root of sleep disturbance and other long term health effects. Vardaxis, Bard and Persson Waye (2018) and Baliatsas et al. (2016) have shown that people are more annoyed by LFN and infrasound, than by higher frequency sounds, and that it may interfere with sleep and concentration. There are also studies showing that some individuals are more sensitive to infrasound than others (Burke, Uppenkamp and Koch, 2020; Jurado and Marquardt, 2020). However, the tests were conducted at much greater loudness levels than are typically present in buildings near wind turbine farms (Zagubién and Wolniewicz, 2020; Baeza Moyano and Gonzalez Lezcano, 2022).

Baliatsas et al. (2016) report that much of the published epidemiological research suffers from poor methodology such as short time exposure to LFN, poor or no control testing and a reliance on subjective data rather than objective medical data. Zagubién and Wolniewicz (2020) discuss the 'nocebo' effect where adverse health symptoms are produced psychosomatically by negative expectations. To eliminate these problems, this research focusses on studies using rats and on studies where responses to infrasound are measured objectively, for example using blood pressure and heart rate readings. The mechanism of the response of the autonomic nervous system (ANS) to infrasound is discussed in Section 4.

One of the most rigorous studies into the effects of wind turbine infrasound on people is reported in Maijala et al. (2021). They studied two groups of people living near a wind turbine farm. The first group of people, called the 'symptomatic group', reported symptoms of stress that were thought to be caused by wind turbine infrasound. The second group of people, called the 'control group', experienced no discomfort from living near a wind turbine farm. The researchers measured the blood pressure and the heart rate of both groups in a series of tests where recorded and acoustically accurate wind turbine infrasound was randomly interspersed with other sounds and they compared the response with each individual's response to a 3-minute standard cold pressor test. They found no difference in the measured response of the two groups when they were unaware of their exposure to infrasound. However, when the two groups were told that they would be exposed to infrasound, the symptomatic group had a strong stress reaction while the control group had no reaction. The reason for this difference is discussed in the context of the ANS in Section 4.

In summary, this work elucidates the phenomenological behaviour of infrasound in order to provide an explanation for its interaction with the built environment. It then examines the effect of infrasound on the central nervous system in an effort to understand why it causes chronic noise stress in a small number of people. The impact of this work is, firstly, to resolve the controversies that rage around the subject and secondly, to provide a reasonable hope of mitigating a problem that causes severe distress to many people.

2. Materials and methods

A systematic literature review was conducted using the three-stage PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) method (Page et al., 2021). The first stage, planning and identification of the initial pool of literature involved the following steps:

- Selecting the initial eligibility criteria, namely, peer-reviewed academic articles, reports and books written in English with a focus on those published since 2012.
- Using Google Scholar and EBSCO Discovery search engines with search terms including a combination of the words infrasound, aperture, attenuation, transmission, buildings, health effect, exposure, central nervous system, autonomic nervous system, noise, wind turbine and soundscape.

In the second stage, the resulting literature was screened to check for relevance to the research themes: phenomenology of infrasound and its interaction with the built environment and the effect of infrasound on the central nervous system. Exclusion criteria were:

- Small studies concerning subjective, anecdotal evidence from small sample sets, and
- Studies on the health effects of exposure to loud noise, and
- Studies on sound above 250 Hz in frequency.

Citations of the remaining literature were used to identify more recent published studies. A total of 58 articles were used (Fig. 2). The final stage was synthesising the literature into the research themes. These are discussed in Sections 3 and 4.

3. The phenomenology of infrasound

Infrasound behaves very differently from audible sound; it travels long distances with far less attenuation and has different interactions with buildings. Infrasound from wind turbines is different from other infrasound sources because it is present over long periods of time, is episodic in nature and is becoming more prevalent as the number of wind turbines increases. Therefore, it is important to understand the effect of wind turbine infrasound on people. These aspects are discussed below. Table 1 summarizes the themes and citations for this section.

3.1. The behaviour of infrasound waves

At 20°C, the speed of sound, c, in air is approximately 343 m/s and the wavelength, λ, and the frequency, f, are related by Eq. (1):

$$c = f\lambda \tag{1}$$

This means that 1 Hz infrasound has a wavelength of about 343 m while 10,000 Hz which is audible sound has a wavelength of about 34.3 mm. With such disparate wavelengths, it is not surprising that infrasound and audible sound behave differently and need to be treated differently. The spherical wave front of audible sound is curved, while infrasound is found to be planar. In order to capture infrasound, McComas et al. (2018) describe 5-element infrasound arrays placed on a 38 m aperture

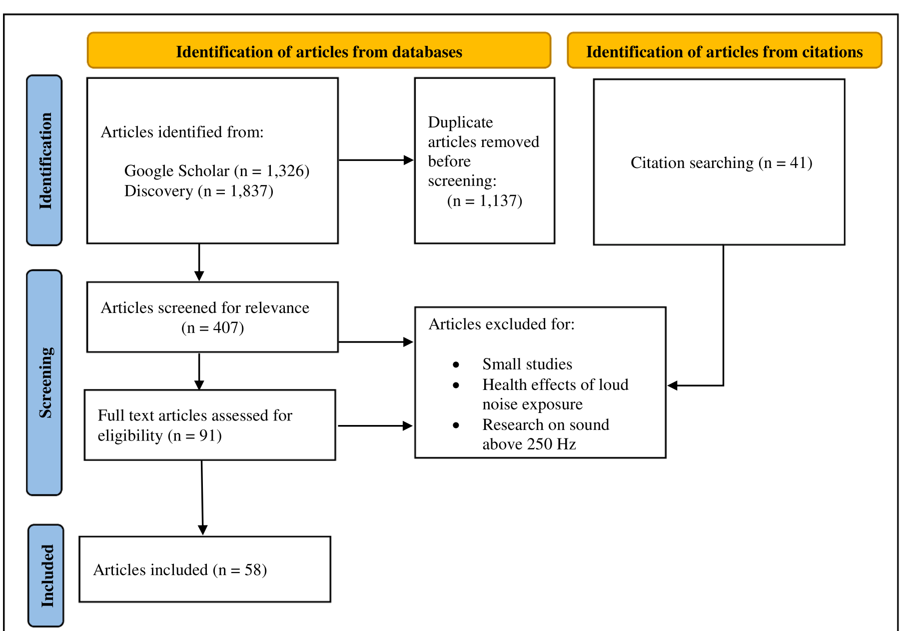

Fig. 2. PRISMA flow diagram of the method. (Source: Page et al., 2021).

Table 1
Review of infrasound phenomenology.

Theme	Citations
Acoustics theory: wave behaviour, propagation, attenuation	Baliatsas et al. 2016; Bedard and Georges, 2000; Evans, Bass and Sutherland, 1972; Javeloyes, Pendás-Recondo and Sánchez, 2021; Keith, Daigle and Stinson, 2018; Le Pichon, Blanc and Hauchecorne, 2010; Le Pichon, Ceranna and Vergoz, 2012; Marchetti et al., 2019; Marcillo et al., 2015; McComas et al., 2018; Mühlhans, 2017; Nuryantini, Zakwandi and Ariayuda, 2021; Sutherland and Bass 2004
Infrasound in the environment: structural interaction, measurement	Baliatsas et al., 2016; Bedard and Georges, 2000; Boczar et al., 2022; Boretti, Ordys and Al Zubaidy, 2018; CCA, 2015; Granzotto, Di Bella and Piana, 2020; Jakobsen, 2005; Keith, Daigle and Stinson, 2018; Krahé et al., 2019; Le Pichon, Blanc and Hauchecorne, 2010; McComas et al., 2018; Sutherland and Bass 2004; Tonin, 2018; van Kamp and van den Berg, 2018; Vardaxis, Bard and Persson Waye, 2018
Wind turbine: sound signature, factors affecting transmission, amelioration in dwellings	Bertagnolio and Fischer, 2021; Boczar et al., 2022; Blumendeller et al., 2022; Boretti, Ordys and Al Zubaidy, 2018; CCA, 2015; D'Amico, Van Renterghem and Botteldooren, 2022; Deshmukh et al., 2019; Jakobsen, 2005; Keith, Daigle and Stinson, 2018; Marcillo et al., 2015; Ö hlund and Larrson, 2015; Okada, Yoshihisa and Hyodo, 2019; Tonin, 2012; Tonin, 2018; Weckendorf et al., 2016

and on a 120 m aperture and provide detail on the signal processing. The sensors are placed, in the horizontal plane, at the centre and on the periphery of a large circle. The diameter of this circle is termed the aperture. Measuring a passing infrasound wave has considerably improved precision if the simultaneous output of several microphones is used, each at a different location. This can also permit the azimuth of the sound source to be determined. Inside buildings, just one microphone is adequate.

When there is a point source of audible sound with power, P, and no obstructions, the sound spreads out radially from the source and the sound intensity, I, varies with distance, r, from the source according to the inverse square law:

$$I = \frac{P}{4\pi r^2} \tag{2}$$

The intensity decrease with distance is called distance attenuation or distance damping and is a conservation of energy effect; energy intensity decreases as the sound waves spread out. It is demonstrated in Nuryantini, Zakwandi and Ariayuda (2021) that Eq. (2) is approximately true over short distances and it assumes that there is no absorption of the sound wave energy (termed dissipation) by the air. This assumption is generally not quite correct; there is also 'classical' attenuation of sound wave energy through atmospheric absorption which is primarily Stokes-Kirchoff energy loss due to viscosity and heat conduction (Evans, Bass and Sutherland, 1972). The latter can be explained in terms of the perfect gas law; sound waves are a succession of pressure fluctuations, which may also be viewed as a succession of temperature fluctuations. High pressure regions have higher air particle collisions and are therefore regions of higher temperature. For a 10,000 Hz sound wave the temperature extremes occurs over about 17 millimetres so that thermal conduction is more rapid and the wave energy dissipates more quickly than for lower frequencies. For a 1 Hz wave, the temperature extremes occur over about 172 metres so heat conduction in the air is relatively small, as attenuation. This means that infrasound suffers much less energy loss through thermal effects compared with audible sound (Mühlhans, 2017). There is additional sound energy absorption through molecular relaxation.

From Stokes' law, classical sound attenuation is approximately proportional to the square of the sound wave's frequency. Therefore, the attenuation of a 10,000 Hz sound is 10^8 times greater than the attenuation of a 1 Hz sound.

The Huygens-Fresnel principle states that every point on a wavefront may be regarded as a point source of secondary wavelets and Javeloyes, Pendás-Recondo and Sánchez (2021) provide an analysis of the theoretical propagation path of a wave viewed as an anisotropic (direction-dependent), rheonomic (time-dependent) cone structure. But the notion of a point source in infrasound is problematic; a very small sphere oscillating in volume with a period of one second would not be detected a hundred kilometres away. Infrasound that is produced from a conical surface, such as a loudspeaker, can only be detected a short distance away, so infrasound can be played to subjects using special headphones. Long-range infrasound propagation is more complex; it depends on the source, on atmospheric conditions and on the location of the source, both in terms of its height above ground and the nature of the surrounding terrain. It is a rule of thumb that wave trains are not affected by obstacles of smaller dimension than the wavelength. Because there are geometrically more small objects than large objects, higher frequencies are affected disproportionally. Infrasound from wind turbines has been measured at distances up to 90 km from the source and infrasound from explosive sources has been measured up to 2,000 km away (Keith, Daigle and Stinson, 2018). A semi-infinite hemisphere of air is not plausible in a troposphere less than 16 km thick so numerical modelling of infrasound attenuation is complex; it assumes that the infrasound behaves as a linear elastic wave that is affected by the characteristics of the atmospheric boundary layer (ABL) such as highly stratified winds and the creation of waveguides extending up some hundreds of metres (Marcillo et al., 2015). Le Pichon, Ceranna and Vergoz (2012) provide a detailed discussion of propagation models based on numerical solutions to the wave equation. These are used in the IMS infrasound detection network. The assumption that infrasound is a linear elastic wave leads to close agreement with empirical data. The attenuation coefficient, A_p, of the pressure wave at a distance R (in km) from the source is given by Eq. (3) (Le Pichon, Ceranna and Vergoz, 2012):

$$A_p\left(f,\ V_{eff-ratio}\right) = \frac{1}{R}10^{\frac{\alpha(f)R}{20}} + \frac{R^{\beta\left(f,\ V_{eff-ratio}\right)}}{1 + 10^{\frac{\delta - R}{\sigma(f)}}} \tag{3}$$

The parameters α, β, δ, and σ are determined by regression on measured data. The first term in Eq. (3) is the near-field attenuation and represents the decrease in SPL due to geometric spreading and exponential decay. The second term is the far-field attenuation due to the different layers of the atmosphere (troposphere, stratosphere, mesosphere and thermosphere) which act as a series of ducts on the sound waves. The phenomenon is analogous to the reflections of sound waves by ocean thermoclines in sonar systems. The attenuation coefficient, A_p, is a function of the wave frequency, f, and the variable, $V_{eff-ratio}$ which is the ratio of the effective sound speed at 50 km altitude and the sound speed at ground level. Le Pichon, Blanc and Hauchecorne (2010) provide a comprehensive discussion. Fig. 3 is a plot of Eq. (3) for varying $V_{eff-ratio}$ (the gray lines) and for $V_{eff-ratio} = 1$ (the red line) for infrasound with a frequency of 1.6 Hz. The plot shows the surprising variation of sound pressure level with distance. In particular, the envelope of grey lines shows that at 5 km from the source the attenuation is about -15 dB, at 20 km the attenuation is about -35 dB, at 100 km the attenuation is about -80 dB, and at 150 km the attenuation varies from -30 to -80 dB. Therefore, depending on the conditions, it is possible for the infrasound to be louder at 150 km from the source than it is at distances of 20 to 100 km from the source. This is very different from audible sound, which

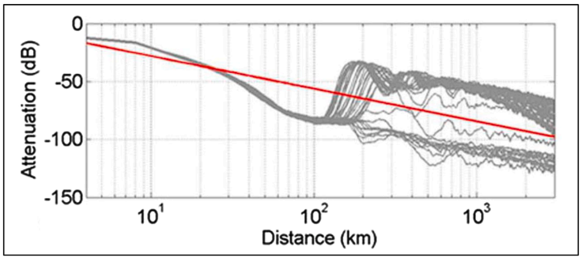

Fig. 3. Attenuation of 1.6 Hz sound with distance. (Source: Le Pichon, Ceranna and Vergoz, 2012).

gets attenuated proportionately with the square of the distance from the source as expressed in Eq. (2).

3.2. Infrasound in the built environment

In the built environment, large structures such as bridges, dams and buildings vibrate at a natural frequency that is in the infrasound frequency spectrum. McComas et al. (2018) describe measurements of 10 Hz infrasound from a bridge and show that features such as highways can act as wave guides, providing enhanced transmission of the sound, while tall buildings can create acoustic shadows. van Kamp and van den Berg (2018) review studies on vibration in dwellings near wind turbines. They discuss the phenomenon of periodic pressure pulses coinciding with the natural frequency of vibration of the structure to create higher than expected SPLs in the dwelling as well as higher frequency, audible vibrations.

We propose that the profound attribute of infrasound in coupling with the lightweight structures of a building can be explained as follows. Structural members generally have some freedom of deflection; a floor can move up and down in the manner of a diaphragm and a wall or window will flex in and out in the same way. Such deflections require relatively small force compared with that required to move them laterally by an equal amount. The large dimensions of infrasound pressure regions will readily apply considerable forces to large surfaces, causing deflection. If the frequency of infrasound and structure agree, there will be large resonant deflections. Specifically, vibration of the floor will set up vibration of a bed on the floor and this vibration may be felt by a sleeping person, even if it is not audible. This vibration can, in turn, produce harmonics which may extend into the audible range. Further, parasitic oscillations of coupled objects may also transduce the subaudible frequency; for example, the shower door may vibrate with an audible rattle. Most lightweight structures in a built environment have low natural frequencies of vibration and are susceptible, in this way, only to infrasound. High frequency sound cannot couple with these elements (Vardaxis, Bard and Persson Waye, 2018).

Infrasound has a peculiar ability to permeate a house, through the walls, doors and windowpanes or through open apertures. Consider the passage of sound through a diaphragm such as a floor, wall or windowpane. In particular, consider a large window, fixed and sealed at its edges. Sound pressure waves hitting the exterior glass cause the pane to vibrate which, in turn, produces pressure waves in the inside air. There is no other possible mechanism; if the distal surface of the diaphragm does not vibrate, the air in the room cannot vibrate from the sound. The window is relatively stiff and although it will deform in a simple mode (the whole diaphragm moves, with maximum deflection at the centre), it will not readily deform in higher modes because it is stiff. In order to deform appreciably, it requires approximately constant pressure over its whole surface. If it is pushed here and pulled there, its reluctance to bend will result in very little deformation at points of high or low pressure. High frequency sound, from a source orthogonal to the window, will necessarily be quite close (because it does not travel far) and will produce concentric circles of high and low pressure. If it strikes the window obliquely, the pressure pattern will be more jumbled and the glass will move very little, being restrained by its stiffness. By comparison, low frequency sound has such large wavelength (17 m for 20 Hz sound) that the full window will fall within a similar pressure regime, whether the source is orthogonal or oblique. If a component frequency of the sound coincides with the natural frequency of vibration of the pane, the effect will be stronger. The same argument also applies to walls, roofs and floors. The bottom line is that infrasound can invade buildings much more readily than audible sound. The transmission of low frequency pressure waves is reduced when rigid materials such as brick and concrete are used in buildings (Granzotto, Di Bella and Piana, 2020).

If there are several open apertures in the walls, each will receive a succession of pressure waves and, by Huygens-Fresnel's principle, each aperture will seem to the auditor in the room to be the source of the sound. For audible sounds, the air in each aperture will not vibrate synchronously because the differing distances from the source to the aperture are significant compared with the short wavelengths. For infrasound, all the apertures will tend to be synchronous, so the vibration of the air in the room will be larger.

In summary, the behaviour of infrasound in the built environment is very different from the behaviour of audible sound. It can travel huge distances, invade structures, couple with the components of structures and transduce its energy into the audible range.

3.3. Wind turbine infrasound and its effect on nearby residences

Many sources of infrasound are intermittent, irregular and of short duration. The exception is infrasound from windmills which is episodic and persists over many hours. This section looks at the characteristics of wind turbine sound signatures and the typical SPL of infrasound from wind turbines.

There are several studies on the mechanism of sound production from wind turbines showing that it is generated primarily from aerodynamic effects and, to a lesser extent, by movement of the mechanical components (Bertagnolio and Fischer, 2021). The aerodynamics involves air flow around the blades in the form of trailing edge noise, tip noise, blunt trailing edge noise and stalled flow noise. These span a wide range of frequencies from infrasound (due to tip noise) up to about 16, 000 Hz. High frequency sound does not travel far from the source so it will not affect people living a few kilometres away (Boczar et al., 2022; Deshmukh et al., 2019). Tonin (2012) and D'Amico, Van Renterghem and Botteldooren (2022) describe impulsive sound from wind turbines at a frequency of about 1 Hz which is the blade passing frequency (BPF) and Boczar et al. (2022) present 2-dimensional power spectral densities (PSDs) from a single wind turbine showing both infrasound and LFN.

Boczar et al. (2022) discuss the difficulty in measuring wind turbine infrasound, both in terms of isolating the source from other infrasound sources, such as the wind, and in terms of the equipment used to measure the acoustic signal. The standard IEC 61400-11 is used for measuring acoustic signals emitted by operating wind turbines in the audible range and the PN-EN 61400-11 standard, Annex A.2 is used to extend the measurements to the IF sound.

Jakobsen (2005) provides an early review of all published measurements of infrasound from wind turbines and notes that there is difficulty comparing measurements because of all the variables (types of wind turbine, wind speed, proximity to other wind turbines, distance of the sensor from the wind turbine, etc.), some of which are not stated in the literature. He cites G-weighted infrasound levels 100 m from the source of about 70 dB from an upwind turbine and 80 to 100 dB from a downwind turbine with a distance attenuation of 3 to 6 dB per distance doubling. In more recent studies, Okada, Yoshihisa and Hyodo (2019) confirm that the highest SPLs of infrasound occur downwind from the turbine and D'Amico, Van Renterghem and Botteldooren (2022) present PSDs showing the effect of wind speed. Öhlund and Larsson (2015) show that, in addition to wind speed and direction, wind turbine sound transmission is strongly affected by local climactic conditions such as temperature, relative humidity and air pressure and the variation in these parameters with distance from the ground. Boczar et al. (2022) report power spectral density plots (PSDs) showing that wind turbines produce infrasound below 9 Hz, around 16 Hz and LFN at about 25 Hz and that increasing wind speed shifts the frequencies slightly higher. Blumendeller et al. (2022) present power spectral density plots (PSDs) measured simultaneously at a wind turbine farm, and outside and inside houses located just over 1 km away. They show that infrasound arises from the blade rotation at the blade passing frequency (BPF) and its multiples and that these are also present inside the houses. When the wind turbine stops, the infrasound tones disappear in the houses. In general, the infrasound SPL is lower inside the houses than it is at the wind turbine, however, just as van Kamp and van den Berg (2018) postulated, the indoor SPL is **higher** for certain infrasound frequencies due to resonance of the structures and different houses have different resonant frequencies. Blumendeller et al. (2022) note the need for more sound monitoring in the audible range to determine whether the effect of infrasound coupling with the structure can produce higher frequency resonances at significant SPLs. There is some evidence to suggest that infrasound in structures causes pictures on walls and objects on shelves to vibrate and rattle which may annoy occupants (Tonin, 2018; Krahé et al., 2019; Jakobsen, 2005) and lead to a lack of 'acoustic comfort' (Vardaxis, Bard and Persson Waye, 2018).

In summary, the sound signature from wind turbines is very variable and complex. However, there is ample evidence that wind turbines produce infrasound and that it couples with nearby buildings, in some cases amplifying resonant infrasound frequencies. It may also produce higher frequency sound and this is an area where more research is needed. Table 1 summarizes the themes and citations that are reviewed in this section.

4. The effect of infrasound on people

4.1. A review of the effect on infrasound on people and animals

Clearly no infrasound problem could exist without a biological response to it. The explanation for the biological response has not received much consideration in the literature, other than dismissing it as a 'nocebo' effect or a by-product of assorted socio-economic factors. As mentioned in the introduction, people are more annoyed by infrasound from wind turbines than from other sources and there are many reports of its adverse effect on health (Baeza Moyano and Gonzalez Lezcano, 2022; Michaud et al., 2016). van Kamp and van den Berg (2018, 2021) and Tonin (2018) review this field and discuss whether two pathologies, namely Vibroacoustic Disease (VAD) and Wind Turbine Syndrome (WTS) occur in people living near wind turbines and having long-term exposure to infrasound. VAD is associated with thickening of cardiovascular structures together with depression, irritability and decreased cognitive skills. WTS symptoms include sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory and panic episodes. Tonin (2018) cites a 2015 Australian Senate Select Committee on Wind Turbines that concluded there was credible evidence from people living near wind turbines complaining of adverse health symptoms. Annoyance and sleep disturbance seem to be the most common symptoms and subjective data from surveys suggests that these get worse as the house gets closer to the wind turbine source (Turunen et al., 2021a; van Kamp and van den Berg, 2018, 2021). The Council of Canadian Academies study confirms the finding that wind turbine infrasound can cause annoyance and sleep disturbance (CCA, 2015). Michaud et al. (2016) note that annoyance increases with increase in SPL and with increasing duration of noise, suggesting that some people become sensitized to the irritation while others become habituated.

Conversely, there are many studies that have investigated the effect of infrasound on people and failed to find measurable health effects. Szychowska et al. (2018) played different sounds to people in an anechoic chamber and asked them to rate their annoyance. When the testers could see wind turbine images simultaneously with the sound, they were more annoyed than when they were just exposed to the sound. Similarly, as mentioned in the introduction, Maijala et al. (2021) present a very careful study, playing infrasound to a group of people with WTS symptoms and an asymptomatic control group and measuring their autonomous nervous system (ANS) response using blood pressure and heart rate. The control group were unaffected by the infrasound and the WTS group only exhibited symptoms when they were told that they were being exposed to wind turbine infrasound (whether it was actually present or not). The infrasound exposure was at 89 dB for several minutes.

Baeza Moyano and Gonzalez Lezcano (2022) review several cases of people living near wind turbine farms who suffered from annoyance and interrupted sleep and discusses the evolutionary value of responding to noise as a source of danger. However, they also note that the percentage of people displaying symptoms is small compared with all people living near wind turbines. This is confirmed in a study by Turunen et al., 2021b who found that only about 5% of residents reported adverse symptoms. Both studies conclude that infrasound may cause a wide range of symptoms in some people, but, aside from annoyance, there is no clear evidence that it does cause the symptoms. The study by Turunen et al., 2021b included a few children who appeared to suffer from wind turbine infrasound related symptoms but the findings were not statistically significant. Zagubién and Wolniewicz, (2020) found that children in school were not affected by wind turbine infrasound and opined that this might be because they were less likely to expect that turbine noise might be problematic. In adults, personal factors and social variables are just as likely to produce symptoms such as annoyance. Peri, Becker and Tal (2020) notes that there may be cultural differences in the perception of wind turbines, probably due to differing familiarity; people who have had little experience of wind turbines are more likely to fear that their noise will be problematic.

Baeza Moyano and Gonzalez Lezcano (2022) point out that laboratory studies have mixed results but that some people appear to be hypersensitive to infrasound, in agreement with Michaud et al. (2016). The studies themselves need to avoid common errors such as exposing people to infrasound for short periods of time (Krahé et al., 2019), using SPLs that are much greater than those near wind turbines and producing symptoms psychosomatically by negative expectations (the 'nocebo' effect). Objective measures such as EEG, ECG, blood pressure, heart rate and nystagmus (eye movement) provide more reliable data than subjective questionnaires asking how the testers feel. Laboratory tests where a narrow sample of infrasound frequencies is used, may fail to capture the entire sound signature in a house near a wind turbine.

4.2. An explanation of chronic noise stress symptoms

Prolonged exposure to loud noise is known to cause neurological disorders such as cognitive decline and hearing loss in both people and rats (Samad et al., 2022; Haider et al., 2020). Like other stressors, noise stress causes activation of the Sympathetic-Adreno-Medullar (SAM) axis leading to the production of stress hormones and a cascade of unpleasant consequences. This syndrome is detailed by Kryter (1972). If the noise persists, most people adapt to it with a mediation response based on homeostasis with activation of the Hypothalamus-Pituitary-Adrenal (HPA) axis. For a detailed description see Goodoy et al. (2018) and Russell and Lightman (2019). For those who cannot adapt, the stress becomes progressively more serious. The factors that allow only some people to develop protective adaptation are very complex (Ellis and Del Giudice, 2019). In extreme tests with rats, sustained levels of stress hormones and neurotransmitters damaged the immune system, organs and tissues, parts of the brain atrophied and there was increased chronic low-grade inflammation and psychological deterioration which manifested as symptoms such as cardiovascular problems, diabetes, cancer, autoimmune malfunction, depression and anxiety (Mariotti, 2015).

Haider et al. (2020) and Seidman and Standring (2010) review the physiological and psychological effects. There is evidence of similar brain damage in rats exposed to infrasound and LFN (Huet-Bello et al., 2017).

It is important to know that the human nervous system has a subsystem called the reticular activation system whose function is to assess subconscious inputs. In particular, the importance of any sound cannot be assessed until the sound has been processed. Obviously, survival down the ages required that our forebears could be alerted to danger when they were asleep and whether or not they were concentrating on the sounds around them. The point is that humans hear everything around them at all times. Consequently, sleep will not insulate them from a persistent noise if they find it disturbing. Rabellino et al., (2019) describe this as the Innate Alarm System (IAS).

The SPL of wind turbine infrasound is not usually above 70dB, which would not normally be classified as "loud" (because the ear is less sensitive to infrasound than it is to audible sound), but it is persistent and there is evidence that some people are sensitized to it. Latremolier and Woolf (2009) describe the sensitization of the central nervous system (CNS) when it is repeatedly exposed to stressors; the properties of the neurons change so that the person reacts even when the source of stress is removed.

The process that occurs is that the sufferers are probably able to perceive some rhythmical input that they associate with windmills. Possibly, but not probably, some of the sufferers might be able to hear infrasound. What is more likely is that the sufferers perceive some interaction between structures in the house and the infrasound. Mostly, windmills are not placed in high occupancy areas, so the environmental sound level is usually very low, perhaps 10-15 dB. The probable sequence of events is that, in very quiet surroundings, some vibration in the house is transferred directly through the coupled floor and bed to the sleeping person or some vibration is transduced by the structure into the audible range. This disturbs the person, who becomes increasingly irritated, and this leads to loss of sleep. Over a period of time, this experience is repeated until the prospect of another disturbed night causes distress. After many such nights, the sufferer learns that the advent of the soft sounds will condemn him to considerable distress. He then enters the syndrome of classic phobias. This is well discussed by Frumeno et al. (2021) and Samra and Abdijadid (2018). A similar phenomenon is observed after severe earthquakes such as those in Japan in 2011 and in New Zealand in 2010 (Honma et al., 2012; Kemp et al., 2011). The stress caused some people to become hypersensitive to small vibrations and to report significant mental health problems such as anxiety, paranoia, sleep problems, depression and dizziness (Beaglehole et al., 2019).

The arachnophobe does not fear that the picture of a spider will leap from the page and do harm to him. The claustrophobe does not fear that the walls will actually close about him and crush him to death. What they fear is the unpleasant sensations that are caused by contemplating spiders or confined spaces. This fear is entirely real, even if the spider on the page is not, and the fear can be measured by biometric responses such as elevated heart rate.

This explains the behaviour described in Maijala et al. (2021), which on the face of it is inexplicable. In this authoritative experiment, excellently reproduced samples of windmill infrasound acoustic signatures were played to two cohorts of test subjects; one cohort claimed to be sensitised to windmill noise and the other did not. Here, test subjects could not hear the actual infrasound profile of windmills as experienced in the house of the subject. This was because the experiment lacked structures to transduce the infrasound into the audible range. Clearly the experiment, excellent though it was, did not adequately represent the experience of infrasound over an extended period in a quiet house that happened to have structures that transduced the sound. The people with the established phobia were just as frightened by the suggestion that there was infrasound in the room as arachnophobes would have been if they were told that there were spiders in the room or claustrophobes told that the walls could slide together until the subject could not move. One of the authors is an arachnophobe and the other is a claustrophobe, so we have real experience of this phenomenon. Not surprisingly, the subject people with WTS reacted strongly when falsely told that wind turbine infrasound was present. The reaction was clearly shown to be genuine by biometric responses.

It seems therefore that sensitivity to wind turbines follows the same pattern as other phobias. Initially, the person becomes aware of the audible sound from the wind turbines in the quiet rural environment. Thereafter, they sense infrasound vibration transmitted through floors and beds while sleeping and/or hear higher frequency noise from harmonics or parasitic coupling in the structure. Over time, the person becomes irritated and suffers a cascade of stress symptoms such as disturbed sleep. The sufferer then learns to fear the experience and becomes hypersensitive and the adverse response can be triggered merely by seeing a moving wind turbine or by being told that a wind turbine is present.

Table 2 summarizes the themes and citations that are reviewed in this section.

5. Discussion and conclusions

The key to understanding the phenomenology of infrasound lies in its extremely large wavelengths and its extremely low attenuation over very long distances. A significant portion of the infrasound from wind turbines can be measured in nearby residences, with dominant infrasound episodes at the BPF. While the level of infrasound is below the threshold of hearing, some residents become sensitized either to the infrasound vibration through floors and beds or to higher frequency, audible sound in the structure, caused by resonance. When this happens, they suffer the symptoms of chronic stress. The autonomous nervous system is involved in much the same way as it is for other phobias.

There is no suggestion that the solution to infrasound sensitivity is to remove all sources of infrasound from the built environment - this is as ludicrous as suggesting the elimination of all spiders to solve arachnophobia, or all small spaces to solve claustrophobia. Wind turbines

Table 2
Review of the effect of infrasound.

Topic	Citations
Biological response to infrasound (in people and animals)	Baeza Moyano and Gonzalez Lezcano, 2022; Baliatsas et al., 2016; CCA, 2015; Boretti, Ordys and Al Zubaidy, 2018; Burke, Uppenkamp and Koch, 2020; Deshmukh et al., 2019; Huet-Bello et al., 2017; Jurado and Marquardt, 2020; Krahé et al., 2019; Latremolier and Woolf, 2009; Møller and Pedersen, 2004; Mühlhans, 2017; Rabellino et al., 2019; Szychowska et al. 2018; Seidman and Standring, 2010; Zagubién and Wolniewicz, 2020
Wind turbine infrasound physiological and psychological effect on people	Baeza Moyano and Gonzalez Lezcano, 2022; Baliatsas et al., 2016; Deshmukh et al., 2019; CCA, 2015; Jakobsen, 2005; Krahé et al., 2019; Maijala et al., 2021; Michaud et al., 2016; Mühlhans, 2017; Peri, Becker, and Tal, 2020; Szychowska et al. 2018; Tonin, 2018; Turunen et al., 2021(a and b); van Kamp and van den Berg, 2018; van Kamp and van den Berg, 2021; Vardaxis, Bard and Persson Waye, 2018; Zagubién and Wolniewicz, 2020
Chronic noise stress, the ANS and phobia	Beaglehole et al., 2019;Ellis and Del Giudice, 2019; Frumeno et al. 2021; Goodoy et al., 2018; Haider et al., 2020; Honma et al., 2012; Huet-Bello et al., 2017; Kemp et al., 2011; Kryter, 1972; Mariotti, 2015; Russell and Lightman, 2019; Samad et al., 2022; Samra and Abdijadid, 2018; Seidman and Standring, 2010

provide a valuable source of renewable energy and are likely to become more prevalent in the future.

This work has explained infrasound behaviour and its effect on people. Future research is needed to determine which frequencies of wind turbine sound signatures are most annoying to nearby residents and whether these can be eliminated through better design of the blades. Solid house construction using concrete and brick, is likely to have less active coupling with infrasound and will therefore generate fewer resonant frequencies, but this is hardly a solution for those who are currently suffering a very real problem.

Boretti, Ordys and Al Zubaidy (2018) suggest that active infrasound cancellation (anti-sound by playing the same sound waves out of phase to cancel them) might be an effective remediation. However, this seems impractical as it is very difficult to create infrasound within an entire structure. A sensible and inexpensive solution would be to monitor problematic houses with sound equipment and accelerometers to measure audible noise and inaudible vibration. This would detect low frequency tympanic vibration of floors. Remediation would involve installing bracing to eliminate the annoying vibrations. Weckendorf et al. (2016) review the bracing design approaches used for damping vibrations in timber floors. Ground floors are easier to brace than upper floors. If an upper floor problem is identified, the bed could be moved to an area where the floor vibrates less. This remediation might be done by the owners of wind turbine farms and would probably be an inexpensive but rewarding public relations exercise.

In order to become more sustainable, there is a global effort to increase the use of renewable energy sources, such as wind. Therefore, wind turbine installations will increase in the future and more residents will be exposed to this source of persistent infrasound. The debate on whether or not the infrasound poses significant health risks to residents has reached an impasse. By addressing the needs of nearby residents, future research can move in a more constructive direction, which will improve the perceptions of wind turbines and ultimately benefit their uptake.

Declaration of Competing Interest

The authors declare that they have no known conflicting financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No data was used for the research described in the article.

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DE GRUYTER OPEN

THE EFFECT OF VARYING DISTANCES FROM THE WIND TURBINE ON MEAT QUALITY OF GROWING-FINISHING PIGS*

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Abstract

This study was conducted to assess the effect of rearing pigs at three different distances from a wind turbine (50, 500 and 1000 m) on the physicochemical properties and fatty acid composition of loin and neck muscles. The experiment was carried out on 30 growing-finishing pigs, derived from Polish Landrace × Polish Large White sows mated to a Duroc × Pietrain boar. The results obtained during the noise measurement showed that the highest level of noise in the audible and infrasound range was recorded 50 m from the wind turbine. Rearing pigs in close proximity to the wind turbine (50 m) resulted in decreased muscle pH, total heme pigments and heme iron as well as reduced content of C18:3*n-3* fatty acid in the loin muscle. Loins of pigs reared 50 m from the wind turbine were characterized by significantly lower iron content (6.7 ppm g^{-1}) compared to the loins of pigs reared 500 and 1000 m from the wind turbine (10.0–10.5 ppm g^{-1}). The concentration of α-linolenic acid (C18:3*n-3*) in loin and neck muscles decreased as the distance from the wind turbine increased. Avoiding noise-induced stress is important not only for maintaining meat quality but also for improving animal welfare.

Key words: pigs, noise-induced stress, muscles, physicochemical properties, fatty acid composition

Farm animals experience some level of stress during the fattening period and prior to slaughter and this may have detrimental effects on meat quality. The magnitude of the effect is generally thought to be a function of the type, duration and intensity of the individual stressors and the susceptibility of the animal to stress (Ferguson et al., 2001). As reported by Ognik and Sembratowicz (2012), intensified and long-lasting stress induces disorders in a daily rhythm of hormones secretion, physiologi-

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cal and morphological changes. These, in turn, are manifested mainly in changes of blood composition, changes in muscle tissue and formation of meat defects. The study performed by Wojtas et al. (2014) demonstrated that heat stress leads to serious changes in physiological and blood parameters in sheep. Yang et al. (2014) indicated that constant heat stress disrupted the pro/antioxidant balance in *longissimus dorsi* muscle with higher malondialdehyde (MDA) content and lower antioxidant capacity.

Noise as a stress factor has been shown to reduce the quality of farm animals life (Chai et al., 2010; De la Fuente et al., 2007; Voslarova et al., 2011). There is experimental evidence that noise exposure may be a potential stressor in farm animal husbandry. The results of the study performed by Kanitz et al. (2005) indicated that exposure of domestic pigs to repeated noise stress caused changes in neuroendocrine regulations, which are characterized by temporal alterations in the responsiveness of the hypothalamic-pituitary-adrenal (HPA) system. They concluded that repeated exposure of pigs to noise levels of 90 dB affected HPA function and resulted in a state of chronic stress that may have negative implications on animal productivity and welfare. Chloupek et al. (2009) also determined a significant negative influence of noise exposure (80 and 100 dB) on the stress and fearfulness of broiler chickens. According to a study performed by Otten et al. (2004) pigs exposed to 90 dB prolonged or intermittent noise increased cortisol, noradrenaline to adrenaline ratio. Pigs are very sensitive to noise and they should not be exposed to constant or sudden noise. Therefore, noise levels above 85 dB must be avoided in buildings where pigs are kept (Fottrell, 2009).

However, there has been little examination of the consequences of the exposure to noise generated by wind turbine on animal health and consequently meat quality. Wind turbines generate audible noise and infrasound which may affect the level of stress in animals, and consequently meat quality (Mikołajczak et al., 2013). Preliminary studies on the reaction of growing geese to the proximity of wind turbines indicated the negative impact of the immediate vicinity of wind turbines on feed consumption, weight gain and cortisol concentration in blood (Mikołajczak et al., 2013). Results of their study suggested a negative effect of the immediate vicinity of a wind turbine on the stress parameters of geese and their productivity. Many previous studies (Choi et al., 2012; De Weerth and Buitelaar, 2005; Kalra et al., 2007) have shown the relationship between cortisol levels and meat quality and generally considered as the primary biomarker of stress (Russell et al., 2012).

In addition, our previous research indicated that noise generated by the wind turbine affected the quality of muscles and the fatty acid profile of abdominal fat of geese (Karwowska et al., 2014). The results showed that the muscles of geese reared at a distance of 50 meters from the wind turbine were characterized by higher pH and TBARS values compared to those reared at a distance greater than 50 m from the wind turbine.

This point seems to be particularly important, as wind energy sector has shown strong growth in the world. By the year 2020, wind turbine installations in the European Union will increase 64% compared to 2013 levels (The European Wind Energy Association, 2014). In this scenario, livestock is expected to be increasingly exposed to factors generated by the wind turbine.

Avoiding stress is important not only for maintaining meat quality but also for improving animal welfare. Animal welfare is defined as providing environmental conditions in which animals can display all their natural behaviors and has been very important in animal production (Koknaroglu and Arkunal, 2013). It is believed that wind energy development may affect animal welfare. Due to the lack of regulations in Poland, wind turbines are often built in close proximity to residential areas and livestock buildings. Thus, animals are exposed to long-lasting stressors generated by wind turbines.

In view of this evidence, we hypothesized that the muscles derived from pigs reared near a wind turbine can be characterized by altered properties determining its suitability for processing. The aim of our research was to assess the effect of rearing pigs at three different distances from the wind turbine (50, 500 and 1000 m) on the physicochemical properties and fatty acid composition of loin and neck muscles.

Material and methods

Animals and their treatment

The experiment was performed on 30 growing-finishing pigs derived from Polish Landrace × Polish Large White sows mated to a Duroc × Pietrain boar. Animals were allotted to 3 experimental groups, each comprising 10 pigs (5 gilts and 5 boars). Animals of each group were reared at varying distances from the wind turbine (with a capacity of 2 MW) in Rapałki near Rypin (Kuyavian-Pomeranian Voivodeship, Poland). Pigs of group I (G-I) were reared at the distance of 50 meters from the wind turbine; group II (G-II) – at the distance of 500 meters from the wind turbine; group III (G-III) – at the distance of 1000 meters from the wind turbine (Figure 1). The same fattening conditions were applied in each experimental group. During the experiment, animals were kept in specially adapted metal sheds that provide protection from external weather conditions such as rain, wind, direct sunlight. Pigs of each group were kept in identical straw bedded pens and were fed identically twice daily, with a commercial complete diet. The fatteners received the same amount of feed, subject to body weight. During the trial, animals had free access to water. The Local Ethic Committee for Experiments with Animals approved all of the experimental procedures relating to the use of live animals. At the end of the fattening period which lasted from about 30 to 80–90 kg body weight (group I – 80.3±2.2; group II – 82.5±3.2, group III – 90.0±3.1) all pigs were slaughtered.

At the abattoir, animals were allowed a 3-hour rest period with full access to water but not to feed. Then, pigs were slaughtered according to standard commercial procedures and split down the midline. The carcass sides were refrigerated in line processing at 2°C. At approximately 1 hour postmortem, two primal cuts: loin (*m. longissimus dorsi* from the area of the last thoracic and first lumbar vertebrae) and the top of the neck (*m. biventer cervicis*, *m. splenius*) were excised from five carcasses of each experimental group (3 gilts and 2 boars). The primal cuts were packed individually into high density polyethylene bags (HDPE) and subjected to evaluation after 3 days of postmortem ageing at +4°C.

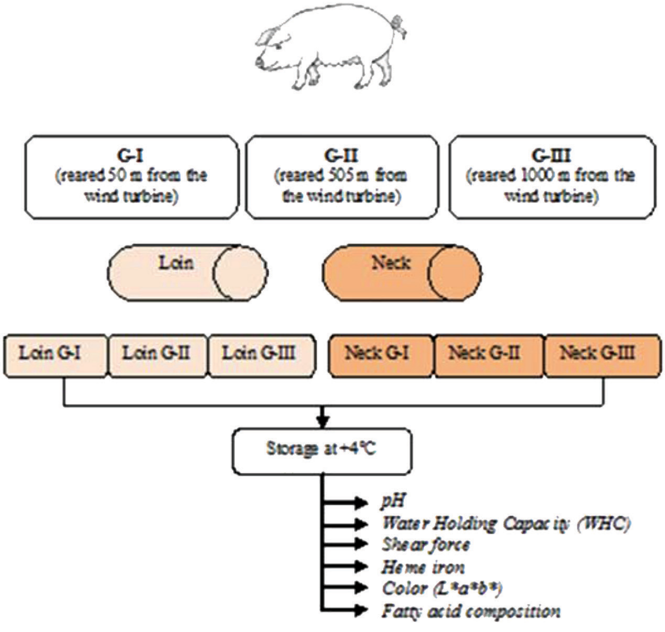

Figure 1. Schematic representation of the experimental design

Measurement of noise generated by wind turbine

During the experiment, the measurements of noise generated by wind turbine were carried out. The noise has been measured inside the sheds. Measurements were taken during the resting phase in order to eliminate the noise generated by animals. Both audible sound and infrasound were measured using a class I sound and vibration analyzer (Svantek SVAN 912 AE).Two different scales were used to weigh all frequencies that are emitted by wind turbine: most audible noises were weighed with the A scale, dB (A), infrasound was weighed with the G scale, dB (G). The noise was measured in each pen in 5 replicates.

Raw meat quality analysis

Measurement of pH

To measure pH, 10 g of minced meat was homogenized with 100 mL of distilled water for 1 min using a homogenizer (IKA Ultra-Turrax T25 Basic, Germany). The pH was measured with a digital pH-meter CPC-501 (Elmetron, Poland) equipped with a pH electrode (ERH-111, Hydromet, Poland). The pH-meter was calibrated with buffer solutions at pH 4.0, 7.0 and 9.0, before pH measurements.

Determination of water holding capacity (WHC)

Measurement of WHC was performed using a centrifugation method (Wierbicki et al., 1962). 50 g of minced meat samples was homogenized with 50 ml of distilled water for 1 min using a homogenizer (IKA Ultra-Turrax T25 Basic, Germany). The homogenates were then centrifuged at 1500 g for 20 min using a MPW-350R centrifuge (MPW Med-Instruments, Poland). Water holding capacity was calculated as: WHC=(M1−M2)/M3×100%, where: M1 – weight of added water (g); M2 – weight of supernatant after centrifugation; M3 – weight of meat in homogenate (g).

Total heme pigments and heme iron determination

A chemical analysis of the total heme pigments from a minced sample of the muscles was carried out to determine the parts per million of hematin per gram of muscle using the method described by Hornsey (1956), with spectrophotometer readings (Nicolet Evolution 300, Thermo Electron Corporation) of absorbance at 640λ. The heme iron content was calculated as described by Clark et al. (1997): Heme iron (ppm g^{-1} meat) = total pigment (ppm g^{-1} meat) × 8.82/100.

Color measurements

Color (L* a* b*) was assessed on the freshly cut surface of meat samples using an XRite Color® Premiere 8200 colorimeter (X-Rite Incorporated, Michigan, USA) with a D65 illuminant and a 10° standard observer (AMSA, 1991). Samples for color measurements were 5 cm thick and excited at the depth of 20 mm. Before color determination, meat samples were wrapped in an oxygen permeable polyethylene film. Every time before use, the instrument was calibrated against a white ceramic calibration tile with the specification of L* = 95.87, a* = –0.49, b* = 2.39 that was wrapped in the same polyethylene film used for the muscle samples, and a light trap.

Fatty acid analysis

Fatty acid profile of meat samples was determined by gas chromatography after conversion of the fats to fatty acids methyl esters (AOCS, 1997). The method of Folch et al. (1957) was used for the extraction of lipids from samples. The fatty acids methyl esters (FAME) were quantified by gas chromatograph method using a fused silica capillary column (Select ™ Biodiesel for FAME, Varian, USA) (30 m × 0.32 mm × 0.25µm film thickness) and flame-ionization detector Varian 450-GC (Varian, USA) at injection volume of 1 mL/min and split ratio 1/50, respectively. Helium was used as the carrier gas. The detector and injector temperatures were chosen as 300°C and 250°C, respectively. The initial column temperature of 150ºC was held for 1 min, increased to 200ºC at 3ºC/min and held for 10 min. Then, it was increased to 240ºC at the rate of 3ºC/min and maintained for 4 min. Quantification of lipid FAMEs was carried out using nonadecanoic acid (C19:0) as an internal standard.

Heat-treated meat quality analysis

Heat-treated meat sample preparation

The loin and neck muscle samples (about 200±10 g) were cured using 2.0% curing mixture (99.5% NaCl, 0.5% sodium nitrite) at 4°C for 24 hours. The samples were individually wrapped in aluminium foil and placed in the oven for roasting at 180°C to an internal temperature of 72°C. The temperature was monitored by chromium-aluminium thermocouples. The muscle samples were cooled and blotted dry. After that, the heat-treated muscle samples were packed individually into the HDPE bags and stored at 4°C overnight.

Shear force measurements

Cylindrical cores (1.25 cm diameter) were cut from the heat-treated muscles, parallel to the longitudinal orientation of the muscle fibers. Warner-Bratzler shear force was determined using a texture analyzer TA-XT plus (Stable Micro Systems Ltd. Surrey, UK) equipped with a V-shaped Warner-Bratzler device (0.9 mm thick). Samples were shorn at a crosshead speed of 100 mm min^{-1}. Data were collected with Texture Expert Exceed Software (Stable Micro Systems).

Statistical analysis

The data were analyzed by one-way analysis of variance (ANOVA) to test the effect of distance from the wind turbine. Measurements were carried out in at least three repetitions for each of the five loins/necks within each group. The results were presented in tables as mean values and standard error (SE). The significance of differences between means for the investigated parameter within muscle types was determined (at the significance level $P<0.05$) by Tukey's multiple range test.

Results

Noise emission in the audible and infrasound range

The results obtained during the noise measurement are presented in Table 1. The average noise values (both audible noise and infrasound) obtained in pen located 50 m from the wind turbine were the highest of all measured pens. When the distance from the turbine was greater, the intensity of recorded sounds was lower. Measurements of noise emitted by the wind turbine, which is audible for humans (A scale), gave the values in the range of 46.1–53.6. Noise measurements in the infrasound range (G scale) generated by the wind turbine allowed determination of the intensity of sound in the range of 56.2–71.0.

Table 1. The mean values obtained during the noise measurement

Distance from wind turbine (m)	Noise level dB (A)	Noise level dB (G)
50	53.6	71.0
500	52.9	68.5
1000	46.1	56.2

Effect of the distance of the wind turbine on pig meat quality

The results of loin and neck pH measurements for each experimental group are shown in Table 2. In the case of loin muscle, the examination of the pH values indicated no statistically significant differences between growing-finishing pigs reared at varying distances from the wind turbine. Neck muscles of animals reared at the distance of 50 m from the wind turbine were characterized by lower pH values compared to those reared 500 m and 1000 m from the wind turbine.

Table 2. pH, water holding capacity (WHC) and shear force values of meat from growing-finishing pigs reared at three different distances from the wind turbine (mean ± SE)

	pH	WHC (%)	Shear force (N)
Loin			
G-I	5.39±0.06	37.8±4.8	50.6±4.2 b
G-II	5.41±0.04	35.7±6.8	34.8±5.3 a
G-III	5.41±0.05	38.3±9.6	39.7±4.8 a
Neck			
G-I	5.87±0.06 a	20.3±4.4	26.8±5.1
G-II	5.90±0.07 ab	16.6±5.7	28.2±8.2
G-III	6.04±0.06 b	16.0±2.4	27.2±7.8

a, b – different letters in the same column (within each muscle) represent significant differences (P<0.05).

Regarding water holding capacity (WHC) of loin and neck muscles, there was no statistically significant effect of the distance from the wind turbine. Results of shear force measurements revealed that loin muscle of G-I was characterized by higher shear force compared to those of G-II and G-III (Table 2). For the neck muscles, no statistical differences were observed in shear force values across groups.

Table 3 shows results of L*a*b* color coordinate measurements taken for the loin and neck muscles. It was indicated that the close proximity to the wind turbine did not result in significant changes in color coordinate L*. Results obtained for redness were more differentiated. Loins of G-I had significantly lower values of coordinate a* than the samples of G-II and G-III. In the case of the neck, no statistical differences were observed in redness values across groups.

The results of total heme pigments and iron content confirmed the results of physical determination of meat color (Table 3). Loins of G-I were characterized the lowest total heme pigments and iron content among all experimental groups.

Table 3. Color coordinates (L*a*b*), total heme pigments and heme iron content of meat from growing-finishing pigs reared at three different distances from the wind turbine (mean±SE)

	Lightness (L*)	Redness (a*)	Yellowness (b*)	Total heme pigments (ppm g^{-1})	Heme iron (ppm g^{-1})
Loin					
G-I	54.1±1.2	–1.0±0.3 a	8.5±0.6	85.9±5.6 a	6.7±0.5 a
G-II	53.5±1.5	1.2±1.0 b	8.2±0.8	119.2±11.2 b	10.5±1.0 b
G-III	56.1±1.7	0.2±0.5 b	8.2±1.1	112.2±18.7 b	10.0±1.7 b
Neck					
G-I	51.4±2.8	5.0±2.2	9.3±1.1	150.8±5.8	13.4±0.5
G-II	49.3±1.0	6.9±0.9	9.9±1.4	160.6±18.2	14.3±1.6
G-III	49.4±1.0	8.8±1.9	10.9±0.8	148.3±9.8	13.1±0.9

a, b – different letters in the same column (within each muscle) represent significant differences (P<0.05).

Effect of the distance from the wind turbine on the fatty acid composition of growing-finishing pig meat

The effect of the distance from the wind turbine on fatty acid composition of growing-finishing pig loin and neck is shown in Table 4.

Table 4. Fatty acid composition (%) of meat from growing-finishing pigs reared at varying distances from the wind turbine

Fatty acid	Loin			Neck		
	G-I	G-II	G-III	G-I	G-II	G-III
C10:0	0.08	0.08	0.08	0.09	0.09	0.08
C12:0	0.10	0.11	0.13	0.14	0.12	0.13
C14:0	1.35	1.45	1.48	1.52 b	1.30 a	1.35 a
C15:0	0.05	0.06	0.09	0.08	0.05	0.07
C16:0	24.32	23.70	23.52	24.51 b	22.89 a	22.79 a
C16:1	3.19	2.79	2.53	3.06	2.07	2.76
C17:0	0.32	0.34	0.57	0.42	0.38	0.44
C17:1	0.31	0.30	0.42	0.38	0.27	0.34
C18:0	13.76	14.33	14.93	13.69 a	17.98 b	13.49 a
C18:1n9c+C18:1n9t	47.24 c	44.28 b	41.21 a	42.63 b	39.89 a	44.03 b
C18:2*n-6*	8.38 a	11.43 b	13.77 c	12.28 a	13.66 b	13.28 b
C18:3*n-3*	0.68 a	0.85 b	1.09 c	0.97	1.04	1.03
C20:0	0.20	0.25	0.22	0.21	0.24	0.18
C20:1	0.00	0.13	0.00	0.00	0.00	0.00
SFA	40.16	40.30	41.01	40.65 b	43.03 c	38.52 a
MUFA	50.73 c	47.48 b	44.16 a	46.06 b	44.22 a	47.12 b
PUFA	9.05 a	12.28 b	14.86 c	13.25 a	14.69 b	14.31 b
n-6	8.38 a	11.43 b	13.77 c	12.28 a	13.66 b	13.28 b
n-3	0.68 a	0.85 b	1.09 c	0.97	1.04	1.03
n-6/n-3	12.32	13.45	12.63	12.66	13.13	12.89
PUFA/SFA	0.22 a	0.30 b	0.36 c	0.32 a	0.34 ab	0.37 b

a, b, c – different letters in the same row (within each muscle) represent significant differences ($P<0.05$).

In three experimental groups of growing-finishing pigs, SFA and MUFA were the predominant components in lipids of loin and neck muscles, whereas the concentration of PUFA was relatively lower. The concentration of C14:0 as well as C16:0 was higher for neck of G-I, but there was no statistical difference for loins. Differences among groups were also found in the concentration of C18:1(n9c+C18:1n9t). With increasing distance from the wind turbine, C18:1(n9c+C18:1n9t) content in loin muscles decreased. The significantly lower content of this fatty acid in neck muscles was observed in the case of growing-finishing pigs from group II. Conversely, the concentration of linoleic acid (C18:2*n-6*) was lower in loin and neck from G-I than from G-II and G-III. The concentration of α-linolenic acid (C18:3*n-3*) in loin and neck muscles decreased as the distance from the place of pig rearing to wind turbine increased.

The content of saturated fatty acids (SFA) in loin muscles was similar for all experimental groups. In the case of neck muscles, SFA was lowest in G-III. Differences among groups were found in the concentration of monounsaturated fatty acids (MUFA). Loins of G-III and neck muscles of G-II had the lowest content of MUFA. The content of polyunsaturated fatty acids (PUFA) was higher for loin and neck muscles of pigs from G-II and G-III than those of G-I. In loin muscles, the content of *n-3* and *n-6* fatty acids was significantly lower for G-I compared to G-II and G-III.

No significant differences were observed for the ratio of *n-6*/*n-3* fatty acids in loin and neck muscles while the effect of the distance from the wind turbine on the ratio of PUFA/MUFA in muscles was noted. When animals were reared in the close proximity to the wind turbine the ratio of PUFA/MUFA was lower in the muscles.

Discussion

Handling at the farm, genetics, the season and preslaughter handling are very important aspects that influence the stress level of the animal and thus are responsible for the development of aberrant meat quality (Van de Perre et al., 2010). While consumers continue to consider sensory and technological quality of meat important issues, they are increasingly concerned with welfare of animals during rearing and at slaughter. Although increasing emphasis has recently been put on ensuring the conditions of animal welfare and stress elimination during the fattening period, only minimal attention has been devoted to examine impact of stress associated with the exposure to noise, in particular generated by wind turbine. Wind turbines generate noise containing infrasound components. On the basis of the results obtained, it can be concluded that the highest level of noise in the audible and infrasound range was recorded 50 m from the wind turbine where growing-finishing pigs of group I (G-I) were reared. When the distance from the turbine increased, the intensity of recorded sounds decreases. Our results are in accordance with those obtained by Pawlas (2009). As reported by Pawlas (2009) the level of noise emitted by wind turbines is in the range of 100 to 107 dB(A) and decreases as the distance from the turbine increases. This has been confirmed also in the studies of Mikołajczak et al. (2013). Their results indicated that when the distance from the wind turbine increased, the intensity of infrasound decreased greatly, and at the distance of 1000 m the intensity was 40 dB. However, the noise values obtained in pens do not exceed the level required by law. According to the Regulation of the Minister of Agriculture and Rural Development dated 15 February 2010, in areas where pigs are kept the noise should not be permanent or induced suddenly, and its intensity should not exceed 85 dB.

On the basis of the results obtained, it can be concluded that rearing pigs in close proximity to a wind turbine (with a capacity of 2 MW) impacts on pH and shear force of muscles. However, the effects observed were dependent on the type of muscle. Neck muscles of pigs reared at the distance of 50 m from the wind turbine were characterized by significantly lower pH values compared to those reared 500 m and 1000 m from the wind turbine while no statistically significant differences between loins were detected. The results are in accordance with our previous research (Karwowska et al., 2014). Noise-induced stress reaction may increase stress hormones that exacerbate the effects of muscular activity on antemortem and postmortem metabolism, consequently affecting rate and extent of glycogen depletion, lactate formation, and pH decline postmortem (Terlouw, 2005). As reported by Aguilera (1994), animals under condition of chronic stress may show rapid postmortem glycolysis, which in turn results in a rapid decline in muscle pH. The previous and current results suggested that the differences in muscle fiber type could result in differences in combating stress and result in alterations in postmortem metabolism between two fiber types affecting the quality of muscles.

The results confirmed no statistical differences in water holding capacity (WHC) between experimental groups. The ability to retain inherent and added water is an important property of meat as it affects both the yield and the quality of the end product. As reported by Andres et al. (2007) water holding capacity is the result of biochemical and physical changes occurring in muscle tissues postmortem and is largely influenced by animal stress, genetics, preslaughter handling conditions and carcass cooling. In contrast, the results of our study did not confirm the effect of noise as a stress factor generated by the wind turbine on the ability to retain inherent and added water by the loin and neck muscles.

L*a*b* color parameters were generally similar across experimental groups, with the exception of differences between a* values for loin muscles. Loins of G-I (50 m from the wind turbine) had significantly lower values of coordinate a* than the samples of G-II and G-III. The results of total heme pigments and iron content confirmed the results of physical determination of meat color. Loins with lower redness were characterized by the lowest total heme pigments and iron content among all experimental groups. Lower contents of heme iron reduce the nutritional value of meat because heme-iron is more available than non-heme iron (Estevez and Cava, 2004).

According to the results of our observations, rearing pigs in close proximity to a wind turbine causes a significant change of fatty acid profile of loin and neck muscles. Fatty acid composition is an important factor in the nutritional quality of muscle and as such has long been a subject of study in meat science receiving considerable attention due to its important role in human health (Raes et al., 2004). Generally, rearing pigs in close proximity to a wind turbine impacts polyunsaturated fatty acids content, in particular C18:3*n-3* fatty acid content of loin muscles. This is in agreement with our previous results (Karwowska et al., 2014) which showed that rearing geese in close proximity to a wind turbine impacts C18:3*n-3* fatty acid content of abdominal fat.

The concentration of α-linolenic acid (C18:3*n-3*) decreased as the distance from the place of growing-finishing pig rearing to wind turbine increased. As is evident from the literature, environmental stress – heat stress in particular – induces the oxidative stress, the term used to describe the condition of oxidative damage as a result of an unfavorable critical balance between free radical generation and antioxidant defenses (Chulayo et al., 2012; Falowo et al., 2014). The condition of oxidative stress results in the degradation of unsaponifiable and polyunsaturated fatty acid fraction of meat lipids and the conversion of oxymyoglobin to oxidized form (metmyoglobin) (Falowo et al., 2014). Thus, the essential α-linolenic acid may be preferentially oxidized, leading to a diminished incorporation into muscles.

In human nutrition, both the content of PUFA and the ratio between *n-6* and *n-3* fatty acids are important (Wood et al., 2008). A high *n-6* PUFA intake can negatively impact human health. The proportion of *n-3* PUFA was significantly lower in the loin muscles of growing-finishing pigs reared 50 m from the wind turbine. However, the *n-6:n-3* PUFA ratio did not differ among the groups. The ratio of *n-6:n-3* PUFA in all the groups was higher than recommended (4:1) (Wood et al., 2008).

In summary, a significant negative influence of noise generated by the wind turbine with a capacity of 2 MW on the quality of growing-finishing pig loin muscles was determined. Rearing growing-finishing pigs in close proximity to the wind turbine resulted in lower pH, total heme pigments and heme iron as well as lower content of C18:3*n-3* fatty acid of loin muscles. In this sense, it is crucial to reduce the exposure of animals to noise generated by wind turbines in order to avoid negative effects on meat quality.

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Original article

Preliminary studies on the reaction of growing geese (*Anser anser f. domestica*) to the proximity of wind turbines

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Abstract

Wind farms produce electricity without causing air pollution and environmental degradation. Unfortunately, wind turbines are a source of infrasound, which may cause a number of physiological effects, such as an increase in cortisol and catecholamine secretion. The impact of infrasound noise, emitted by wind turbines, on the health of geese and other farm animals has not previously been evaluated. Therefore, the aim of this study was to determine the effect of noise, generated by wind turbines, on the stress parameters (cortisol) and the weight gain of geese kept in surrounding areas. The study consisted of 40 individuals of 5- week- old domestic geese *Anser anser f domestica*, divided into 2 equal groups. The first experimental gaggle (I) remained within 50 m from turbine and the second one (II) within 500 m. During the 12 weeks of the study, noise measurements were also taken. Weight gain and the concentration of cortisol in blood were assessed and significant differences in both cases were found. Geese from gaggle I gained less weight and had a higher concentration of cortisol in blood, compared to individuals from gaggle II. Lower activity and some disturbing changes in behavior of animals from group I were noted. Results of the study suggest a negative effect of the immediate vicinity of a wind turbine on the stress parameters of geese and their productivity.

Key words: wind turbine, domestic goose, anser anser, noise, cortisol

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Introduction

Sound waves are divided into infrasound, audible sounds and ultrasounds (Pawlas 2009). Infrasound is a sound or noise with a frequency spectrum ranging from 1 to 20 Hz (Augustyńska 2009), and is perceived not as a "normal" tone, but rather as a pounding and the feeling of "tightness" in the ears (Pawlas 2009).

Continuous sounds (both audible and infrasound noise) may be produced by wind turbines. The level of noise emitted by wind turbines, ranges from 100-107 dB and decreases as the distance from the turbine increases (Pawlas 2009).

Currently, there is no European and international legislation concerning the exposure limit values for infrasound (Augustyńska 2009). The results of animal studies suggest considerable nuisance and harmfulness of infrasound, and therefore indicate the need to determine the safe level of noise.

The effect of infrasound on animals under laboratory conditions, has often been studied (Nekhoroshev and Glinchikov 1992, Bohne and Harding 2000). During such studies the adverse effects of infrasound were noted in animals such as mice, rats, guinea pigs, chinchillas, dogs, monkeys and other mammals. Changes may be observed in the cardiovascular system (narrowing of arteries and coronary vessels) (Alekseev 1985), in the brain (Nekhoroshev and Glinchikov 1992) and in the lungs (thickening of alveoli and filling of the pulmonary acinus with erythrocytes, the partial destruction of the acinus and the disruption of blood vessel walls) (Svidovyi and Glinchikov 1987). Infrasound with a very high intensity may cause serious damage to ear structures (Johnson 1980). Continuous exposure may cause significant changes in comparison to intermittent exposure. In chinchillas constantly exposed to infrasound at a frequency of 0.5 Hz and a level of 95 dB, damage to hearing may occur after 2 days up to 432 days of exposure (Bohne and Harding 2000). In humans exposed to infrasound some psychological and physiological changes such as fatigue and wakefulness disorders, related to changes in the central nervous system, have been reported (Landström et al. 1983).

Under natural conditions, infrasound generated by wind turbines reduces species diversity during nesting (Francis et al. 2009) and may have negative effects on the behavior, communication skills, health and survival ability of birds (Barber et al. 2010), and also on squirrels' ability to recognize predators (Rabin et al. 2006). In the case of animals living fenced in, held without the possibility of free movement, noise can lead to an increasing level of stress (Flydal et al. 2004). In domestic animals, such as sheep and horses, the noise from wind turbines at a level of 60-75 dB may cause acceleration of breath, rapid heart rate, increased alertness and reduced grazing time (Ames and Arehart 1972). Increased cortisol secretion in sheep was observed as a response to stress caused by exposure to the noise emitted during the shearing procedure (Hargreaves and Hutson 1990). However, more research showing the impact of noise emitted by wind turbines on farm animals is needed.

Glucocorticoids (GCs): cortisol and corticosterone, are the front-line hormones in overcoming stressful situations (Palme et al. 2005). Although corticosterone is considered to be the dominant avian glucocorticoid and is well known as a stress hormone in birds (Koren et al. 2012), there are some papers demonstrating that birds also produce cortisol (Walsh et al. 1985, Schmidt and Soma 2008, Sohail et al. 2010, Swathi et al. 2012, Jadhaw et al. 2013). We, therefore, examined the changes of cortisol concentration in blood of geese as a response to the possible stress caused by infrasound generated by a wind turbine.

Materials and methods

The study included 40 individuals of 5-week-old domestic geese *Anser anser f. domestica*, divided into two groups of 20 individuals each. The first gaggle (group I) remained within 50 m from the turbine (with a capacity of 2 MW) in Rapałki near Rypin (Kuyavian-Pomeranian Voivodeship, Poland), the second one (group II) within 500 m. Animals from both groups had continuous access to feed and water and were fed identically, with a commercial mixture of complete feed. The composition of the mixture is presented in Table 1. The birds were kept on a covered surface with paddock (1 m^2 per individual). The study lasted for 12 weeks, and during that time, in order to analyze the concentration of cortisol, blood was collected between 9:00 to 10:00 a.m. from 20 randomly selected animals (10 individuals from

Table 1. Composition of commercial mixture of complete feed.

Component	%
Crude protein	19.00
Crude fiber	4.50
Oils and fats	3.80
Crude ash	5.30
Calcium	0.80
Organic phosphorus	0.56
Sodium	0.17
Lysine	0.93
Methionine	0.38

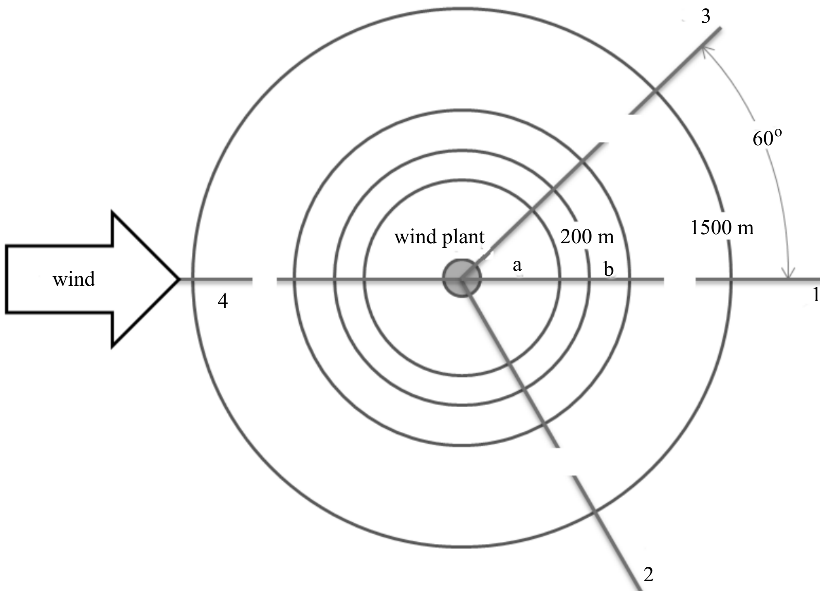

Fig. 1. Scheme of vibration, noise and infrasound measurements around the wind plant: 1, 2, 3, 4 – measuring directions; a – the diameter of the first circle resulting from PN-EN 61400-11; b – distance between following circles (100 m).

each group, 5 males and 5 females). The procedure was performed three times, in the 5th, 10th and 17th week of rearing. Venous blood was collected in order to obtain serum which, until assessment, was stored deep-frozen (-80°C) in small aliquots. The cortisol concentration in the serum of birds from both gaggles was measured by using the ELISA method with the use of the R & D System diagnostic kit. Reproducibility of the method for intra-assay precision was CV < 9.3%, and for inter-assay precision CV < 12%.

The geese were weighed during the 5th, 10th and 17th weeks. The results were statistically analyzed using Statistica 8.0 PL.

In the course of the experiment the measurements of noise were taken as follows: 10 times at 4 designated measuring points situated 140 m away from the turbine and 5 times within 50 m from the turbine, at the place where the geese were kept. In addition, measurements (in four directions) at a distance of 200 m from the plant and at every subsequent 100 m, up to 1500 m, were made. Both audible sound and infrasound were measured using a class I sound and vibration analyzer (Svantek SVAN 912 AE). Measurements of noise generated by the wind turbine were assessed according to marker points designated in accordance with PN- EN 61400-11 (Fig. 1). A microphone located on a special plate was used to measure noise. The results were adjusted based on the reference wind speed and roughness of the terrain.

Results

Noise measurements

Noise emission in the audible range

During the experiment, ten measurements of noise generated by the Vestas wind turbine (2 MW) were performed. Declarations of the wind turbine manufacturer, concerning acceptable noise emission, are presented in Table 2. The measurements were performed at 4 measuring points, in accordance with PN- EN 61400-11 and at the location of geese gaggles (within a distance of 50 m from the turbine), at a distance of 200 m from the plant and at every subsequent 100 m, up to 1500 m. During measurements the wind speed and its direction were observed. The speed was 5.9 m/s and the wind was blowing in the direction of 12 degrees N-E.

Table 2. Declarations of the manufacturer concerning levels of maximum noise emission.

Wind speed [m/s]	Noise level [dB(A)]
4	94.4
5	99.4
6	102.5
7	103.6
>8	104.0

Table 3. Results for measuring site 1 [dB(A)].

Measure-ment	1	2	3	4	5	6	7	8	9	10	Average value
Value	87.0	87.0	83.0	79.1	81.0	79.8	79.6	79.5	79.3	82.0	81.73

Table 4. Results for measuring site 2 [dB(A)].

Measure-ment	1	2	3	4	5	6	7	8	9	10	Average value
Value	105.0	105.0	104.0	103.5	103.0	101.5	101.0	98.0	97.5	97.0	101.55

Table 5. Results for measuring site 3[dB(A)].

Measure-ment	1	2	3	4	5	6	7	8	9	10	Average value
Value	99.0	99.0	98.5	98.0	92.0	87.0	90.0	89.0	91.0	85.0	92.85

Table 6. Results for measuring site 4 [dB(A)].

Measure-ment	1	2	3	4	5	6	7	8	9	10	Average value
Value	102.0	102.0	104.0	103.5	104.0	101.5	101.0	100.0	99.5	97.0	101.45

Measurements of noise emitted by the wind turbine, which is audible for humans (A scale), gave the value of the sound intensity at the distance of 140 m from the turbine. At site 1 the average value was 81.73 dB, at site 2 – 101.55 dB, site 3 – 92.85 dB and site 4 – 101.45 dB. Detailed results of measurements for each point are summarized in Tables 3-6.

At the site where the geese of group I were kept (50 m from the turbine), the average sound intensity, obtained from 5 measurements, was 56.3 dB, while at the place where the second gaggle was kept the mean volume was 58.33 dB.

Noise emission in the infrasound range

Noise measurements in the infrasound range (Lin scale) generated by the wind turbine in Rypałki allowed determination of the intensity of sound at the point 50 meters from the turbine (the location of geese), where the average value was 94.5 dB, while the average value in site 1 was 99 dB, site 2- 105 dB, site 3- 96.23 dB and site 4- 98.63 dB. When the distance from the turbine was greater, the intensity of recorded infrasound was significantly lower. At a distance of 300 m the intensity was less than 100 dB, at 500 m – 80 dB, while at 1000 m it was approximately 40 dB.

Cortisol

Steroid hormones function as mediators of essential metabolic and energy-allocation processes. GCs, cortisol and corticosterone, mobilize energy storage in response to a crisis (Koren et al. 2012). Although corticosterone is considered to be the dominant avian glucocorticoid and is well known as a stress hormone in birds (Koren et al. 2012), there are some papers demonstrating that birds may also produce cortisol (Walsh et al. 1985, Schmidt and Soma 2008, Sohail et al. 2010, Swathi et al. 2012, Jadhaw et al. 2013). Cortisol is secreted by the adrenal cortex in response to the adrenocorticotrophic hormone produced by the pituary gland (Kerr 2002) and has a multidirectional mode of action. The best known is its effect on the metabolism and the immune system (Lisurek and Bernhardt 2004) and is associated with the stress response. During stress it acts as a neuroendocrine mediator in organs and tissues such as the brain, cardiovascular system, immune system, adipose tissue and muscle (De Kloet et al. 1998).

Table 7. Concentration of cortisol in blood of geese from both groups [ng /mL].

Age	5th week		10th week		17th week	
Group	I	II	I	II	I	II
♂	x – 12.40	x – 6.14	x – 31.3	x – 9.64	x – 34.08	x – 11.23
♀	x – 11.24	x – 6.72	x – 34.12	x – 8.58	x – 34.35	x – 13.99
x for whole group	11.92*	6.43*	32.71*	9.11*	34.12*	12.61*
SD for whole group	1.63	2.13	6.3	1.65	8.9	9.10

* highly statistically significant differences between average values ($p < 0.001$)

Table 8. Body weight of geese from both groups [kg].

Age	5th week		10th week		17th week	
Group	I	II	I	II	I	II
♂	x – 3.10	x – 2.99	x – 4.55	x – 4.80	x – 7.8	x – 8.98
♀	x – 2.67	x – 2.82	x – 4.31	x – 4.52	x – 7.1	x – 7.65
x for whole group	2.89	2.91	4.43	4.66	7.45*	8.31*
SD for whole group	260.18	104.74	173.61	153.83	0.59	0.84

* statistically significant differences between average values ($p < 0.05$)

During the 5th, 10th and 17th week of rearing, in order to determine the concentration of cortisol in the serum of birds, blood samples were collected from 10 geese selected randomly from each experimental group. The results are summarized in Table 7.

The first measurement of cortisol concentration in blood was performed 48 hours after transport and placement of the birds at the sites located at a distance of 50 and 500 meters from the wind turbine. In the 5th week, the average concentration of cortisol in the geese blood from group I was 11.92 ng/mL, while in group II – 6.43 ng/mL. In the 10th week the average cortisol concentrations for group I and II were 32.71 ng/mL and 9.11 ng/mL, respectively. In the 17th week, the cortisol concentration in group I was 34.12 ng/mL, and in group II – 12.61 ng/mL.

The differences in the cortisol concentration in the blood of animals from both gaggles, in the 5th, 10th and 17th week of rearing, were found to be highly significant ($p < 0.001$).

Body weight

In the 5th, 10th and 17th week of rearing geese were weighed, each time 10 geese from both groups were chosen. The result of body weight measurements, obtained in the subsequent weeks, are presented in Table 8.

In the 5th week, the body weight of birds from both gaggles were similar. In the 10th week, the average body weight of animals in group I was approximately 230 g lower than the average weight of birds from the second gaggle. In the 17th week, the difference in average body weight between the two groups was greater (860 g) and was statistically significant ($p < 0.05$). Geese from gaggle I tended to eat less feed. The daily feed intakes are presented in Table 9.

Table 9. Daily feed intake by geese of both groups [g].

Week of rearing	Group I	Group II
5	305	340
10	730	780
17	800	1030

The results obtained in the 10th week of rearing showed sexual dimorphism. The body weights of males from both groups were higher by 280 g in group I and 240 g in group II, than the weight of females. Sexual dimorphism in 17-week-old birds was even more noticeable. The body weights of males were higher (by 700 g in group I and 1330 g in group II) than the body weight of females.

Discussion

Noise measurements

The lowest level of noise in the audible range was recorded at measuring site 1 and the highest at site 2. Mean values of sound intensity at sites 2 and 4 are in accordance with the noise intensity value specified by van den Berg (2004) for Dutch turbines, and was 103 dB(A). According to Pawlas (2009), the level of noise around the turbine is within the range of 100 to 107 dB(A). This information is in accordance with results obtained from sites 2 and 4. The noise levels measured at sites 1 and 3, were lower than the noise levels at 2 and 4; since these sites were located opposite each other, different levels of noise may be associated with wind direction. Sites 1 and 3 were located on the leeward side, which explains the lower average noise value, while sites 2 and 4 were located on the windward side, and therefore the mean values of sound intensity were higher.

Results of measurements of the noise level, with an average wind speed of 5.9 m/s, ranged up to 103.6 dB(A), and therefore were within the acceptable range specified by the manufacturer. However, in the case of measurements of infrasound, results were higher than those reported by Golec et al. (2006).

Cortisol

48 hours after transportation and placement of the birds at the sites, located at a distance of 50 and 500 meters from the wind turbine, the cortisol concentration in the blood of geese from group I was significantly higher than the concentration of cortisol in animals from group II. In addition, the geese of gaggle I exhibited reduced adaptability and their behavior (reduced physical activity and feed intake) indicated exposure to stress.

In the 10th week the average concentration of cortisol in the blood of birds from group I was significantly higher than the concentration of cortisol in geese from group II. Also in the 17th week of rearing the concentration of cortisol in the blood of birds kept in the immediate vicinity of the wind turbine was noticeably higher than in the geese that lived at a distance of 500 m from the turbine. The differences in cortisol concentration recorded during all three measurements, between the two groups of birds, were found to be highly statistically significant ($p < 0.001$).

After 48 hours, geese from group I had twice the cortisol concentration in blood compared to group II. In the 10 week of the experiment, the concentration of cortisol in the blood from group I was 3.5 times higher than the concentration of cortisol in the blood from group II. In the 17th week, the cortisol concentration in the blood of birds from group I, compared to geese from the group II, was 2.7 times higher, so it is possible to assume that even though there are some significant differences in the cortisol concentration in the blood of animals from both groups, there is a tendency which suggests that geese may become accustomed to a stressor.

In the 5th week, males from gaggle I had a higher cortisol concentration in blood than female geese; in gaggle II the result was opposite. In the 10th week, a higher concentration of cortisol in the blood of females from group I was noted, but in group II the result was opposite. At the end of the study in both gaggles females had a higher concentration of cortisol in blood than males, however, the difference was not sufficiently significant to claim that gender influences sensitivity to infrasound.

Moreover, the concentration of cortisol in the blood of geese increased with the time of exposure to the immediate vicinity of the wind plant.

All three successive measurements of cortisol concentration showed a higher concentration of "stress hormones" in birds kept at a distance of 50 m from the turbine. The lower cortisol concentration in animals kept at a distance of 500 m may indicate that this distance is safer for animals but still not safe enough, as mentioned below.

In birds, due to their endocrine dissimilarity, the corticosterone concentration during the stress response is commonly tested, and there are few publications on the change in the cortisol concentration in the blood of birds that are influenced by a stressor. Sohail et al. (2010) examined the impact of cyclic heat stress on serum cortisol concentration in broilers. Tokarzewski et al. (2006) studied the impact of the stress caused by transportation on the changes in the cortisol concentration in broiler blood. In the studies mentioned above, the results for control groups were as follows: 1.04 ng/mL (mean) (Sohail et al. 2010) and 1.55 ng/mL (mean) (Tokarzewski et al. 2006), whereas in the experimental groups the results were: 1.91 ng/mL (mean) and 9.26 ng/mL (mean), respectively. In the present study, all results of the cortisol concentration were higher than the control values outlined above. The concentration of cortisol, determined in both gaggles, in every week of rearing (except for the concentration of cortisol in geese from group II in the 5th week), was also higher than concentrations of "stress hormones" obtained in the experimental groups by Tokarzewski et al. (2006) and Sohail et al. (2010). This information suggests that infrasound noise may be a very serious source of stress. In addition, it was noted that the cortisol concentration in the animals from group II was higher than the control concentration, which may therefore suggest that the distance of 500 m from the turbine is still not a safe distance.

The reaction of the birds confirmed that geese have a sensitive sense of hearing and are responding to both audible sounds and infrasound.

Furthermore, a change in the animals' behavior was observed. Birds of group I, for the most part, remained in a compact group and showed less physical activity, while individuals from gaggle II moved freely. This change is likely to result from the exposure of the animals to chronic stress and may be associated with a higher concentration of cortisol, as was shown for birds from group I.

The literature review indicates that any stress, particularly mental, is accompanied by an excessive secretion of the adrenocorticotropic hormone (De Jong et al. 2001). The effect of the stress source on cortisol secretion has been confirmed in other species, including sheep (Hargreaves and Hutson 1990). The increased secretion of cortisol may be harmful to the health of geese, as steroid hormones suppress the immune system, resulting in increased susceptibility to infections with bacteria of endogenous origin (De Jong et al. 2001).

Body weight

In the 5th week, the body weights of birds from both groups were similar. In the 10th week, the average body weight of animals in group I was lower than the mean weight of individuals from gaggle II. Seven weeks later, the difference was even greater and was statistically significant ($p < 0.05$). The mean body weight of both groups of animals, in 10 weeks of rearing, was lower than in the studies of Biesiada-Drzazga et al. (2006). Depending on the experimental group, the authors reported that the male's body weight was from 5.29 to 5.61 kg and for females from 4.88 to 5.11 kg.

In the 17th week the body weight of geese from group I was much lower, but achieved weights in both groups were satisfactory and higher than those found in the literature. During 17 weeks of rearing, Kłos et al. (2010) obtained a weight of 5.74-6.00 kg for males and from 5.18 kg to 5.38 kg for females. Similarly, Łukaszewicz et al. (2008) reported lower body weights – 7.09 kg for males to 6.30 kg for females. Moreover, in our experiment, sexual dimorphism was observed. The greatest differences in body weight between the sexes were found in the 17th week of rearing.

At the end of the study, the differences in the body weights between birds from both groups were found to be statistically significant ($p < 0.05$). Animals kept near the wind turbine had about 10 percent lower body weight than those kept at a distance of 500 m from the turbine. The lower body weight of group I was caused by reduced feed intake. Animals ate less willingly, which could have resulted from the stress caused by infrasound noise emitted by the wind turbine.

To sum up, the results of measuring noise generated by the wind turbine are in accordance with the results obtained by other research (van der Berg 2004). When the distance from the turbine increased, the intensity of infrasound decreased greatly, and at a distance of 1000 m the intensity was 40 dB. Geese from the gaggle which was kept at a distance of 50 m from the turbine, grew slower, gained less body weight (by 10 %) and had a higher concentration of cortisol in blood, compared to birds reared 500 meters away from the wind plant. It was also noted that even the distance of 500 meters cannot be considered a safe one; this was confirmed by the results of infrasound measurement and cortisol concentration in blood, which exceeded the control values.

In addition, cortisol concentration increased with the residence time in the vicinity of the wind turbine. Differences in both weight and cortisol concentration were proven to be statistically significant. The cortisol concentration in both groups, which was higher than the concentration in the control groups, could have resulted from stress caused by the noise generated by the wind plant. Stress may have caused the disturbing changes in behavior.

The results indicate the negative impact of the immediate vicinity of wind turbines on feed consumption, weight gain and cortisol concentration in blood. Nevertheless, further studies, with a larger number of animals and with a variety of distances, are needed, so that the safe distance appropriate for keeping animals can be determined.

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July 21, 2023

Mayor Helen Acker and Planning and Development Board Members-

Please take into consideration the following requests for **More Rigorous Impact Studies** and **Alternatives** outlined below in reference to the New Leaf Energy proposed windmill project in Oneida, New York.

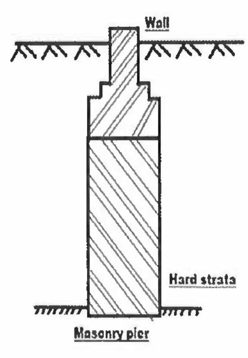
The contractor didn't seem prepared to answer many of the questions that were posed at the first session during the second session. Most responses by New Leaf Energy were "we will do that" or "we'll make everyone whole", **both unfortunately with no explanation in specifics when, how, or why it is the best path forward.** Lots of sharing **without substance** occurred, with the contractor relying on the energy of the neighbors that distracted from substantial, scientific, and proven facts being shared to support their claims.

Be assured it is not an issue of residents not wanting to embrace, contribute and expand environmental stewardship, it is what is missing in the conversation between the public and New Leaf Energy before an in-reversible action occurs. I assume you would agree legally agree until they show impact studies and specifically clearly answer all questions that have ***now twice*** been requested by the public that they have not met the legal threshold of full diligence of being transparent.

Construction Considerations

1. New Leaf Energy explained the method of establishing a pad on site to secure the windmill. In their explanation they may have underplayed the impact of blasting 12(+) feet deep into the shale rock (see photo of shale rock fragileness). Based on a conversation with the United States Army Corps of Engineers Louisville District, who have and had many projects in the New York region. They stated there are numerous methods of installing "foundation bases" to properly secure a windmill in such conditions as this project. Have they considered all the possibilities?
    a. Shallow Matt Extension- This so somewhat close to is what New Leaf Energy offered as their proposed foundation. The Pros are its easy to build with a short construction period. The Cons are that it requires heavy excavation typically with basting, more concrete and steel, and not environmentally friendly as a result or water shear and displacement from the footprint it takes from the normal flow the surrounding area would have in its natural environment- could alter hydrology.
    b. The Underneath Pier Foundation- This is what the United States Army Corps of Engineers Louisville shared as a less environmental impactful method. The Pros are that it can hold a large capacity, there is minor settlement, needs a small footprint, and is equivalent to drilling a series of wells lessening the effects of hydrology impacts. The cons are it is costly and can be complicated to install. The diagram below shows one pier (of a series needed) for this foundation.

Underneath Pier Foundation



Shale Rock Formation

2. Has the City of Oneida ever had a commercial windmill or turbine installed in its domain? Where do the standards that New Leaf Energy is being held accountable for come from in reference to the method of construction, i.e., just as a new home or remodel standards for foundation, framing, and electrical would are? Have and how have these standards been tested and verified by expert industry standards (are these available for review?) to ensure that full diligence has occurred in reference to the best interests of the Oneida taxpayers?
3. According to TWI Ltd Institute "a good quality, modern wind turbine will generally last for 20 years, although this can be extended to 25 years or longer depending on environmental factors and the correct maintenance procedures being followed. However, the maintenance costs will increase as the structure ages." What is the plan for decommissioning (plan and responsible party) the Windmill/Turbine if after 20+ years it isn't cost effective to repair or update? New Leaf Energy offered a bond would be in place to "bring conditions back to original conditions." What type of bond and specifications will the city require and why?
4. The property owner at the council meeting under his own omission made the comment that his reasoning for wanting to put the windmill in was for a legacy for his family in knowing what they did to **save the environment.** I would challenge the owner that installing solar panels instead in the space would meet his objectives and be safer with less possible impacts. According to Inspire Clean Energy approximately 24 solar panels equal to one 5kW wind turbine (New Leaf Energy is proposing a 4+ kW turbine). According to Coldwell Solar, as in this landowner's case, he owns 150+ acres, 2000 solar panels can fit in one acre of land, thus in his case equaling 300,000 solar panels (producing the equivalent of 125 windmills). Solar panels are easily able to change out to confirm with technological advances, where windmills are not. **This is an alternative all the neighbors would prefer in reducing the possible threat of water disruption or loss, while still leaving his family a viable revenue legacy and adding to the preservation of the environment.**

Environmental Considerations

1. As was expressed as the number one concern by every neighboring individual present at the meeting to the proposed windmill, the fear of the **"unknown" of losing well water is possibly imminent if blasting occurs.** The United States Army Corps of Engineers Louisville highly suggested and indicated that if it was one of their projects that **would require both a geological and hydrological study** to indicate the probability of the water flow being challenged to preexisting neighboring wells. As was shared by two attendees at the last meeting, they both had instances where neighboring blasting terminated their water source, this **alone shows a high possibility of this occurring again**. Below is a photo showing the fragileness of shale rock and how easily it can be diverted in reference to water flow. We would still like to see a bonded commitment that if water is lost as a result of the project that they will bring "city water" to the residents, as challenged during the meeting by the Council member to New Leaf Energy. Their "knee jerk" response of it depends on the cost and backtracking to installing water catchments (see below) doesn't seem reasonable in making residents "whole" as they have promised from the beginning, as well as the risk of pathogenic micro-organisms. **More importantly we would like numerus contingency plans, more than "then we (New Leaf Energy) will make you whole."**

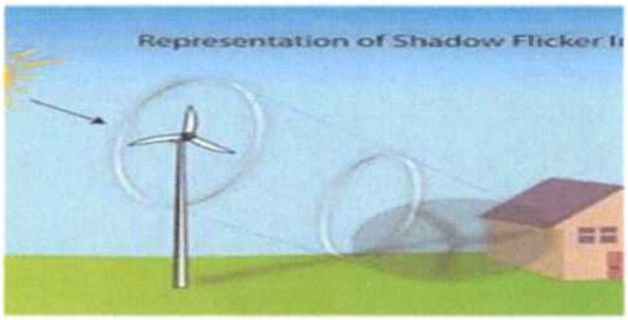
Shale Rock Water Flow and Formation

White Lines are Waterflow Through Shale.

Water Catchments

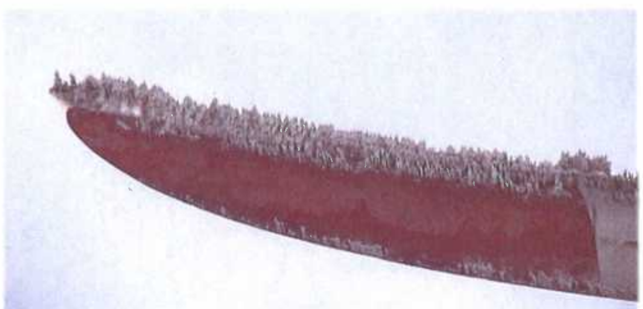
2. The effect of "Wind Turbine Shadow Flicker." Shadow flicker is the effect of the sun (low on the horizon) shining through the rotating blades of a wind turbine, casting a moving shadow through constrained openings such as the windows of neighboring properties. This can result in health issues for individuals. This includes the close approximately to residents with FAA required lighting. According to the FAA all wind turbines at or greater than 500 ft (152.4 m) AGL, each wind turbine should be lit with two FAA L-864 red flashing lights on the nacelle, regardless of their location within a wind farm- possibly another reason to have a lower tower in reducing the environment and resident impact as only one light would be needed. A shadow flicker study should be done.

Shadow Flicker



3. The effect of "icing" during the winter that offers the possibly of "up to nearly one foot thick of ice build-up and release" that offers a treat to neighboring homes and residents. What if any cold weather and anti-icing technologies are going to be used, and what maintenance plan is there for the removal of the fallen ice? The diagram below shows this possible icing issue.

Blade Icing



4. Based upon a conversation with the U.S. Fish & Wildlife Service on the bald eagles in this area, a study should be done to ensure no impact or remediation is established as they are still protected under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act.
5. Health Issues have been recorded in studies of people who live in close proximity to wind turbines, as in our neighboring citizens case, have reported they experience symptoms as dizziness, nausea,

the sensation of ear pressure, tinnitus, hearing loss, sleeping disorders, headache and other symptoms. These symptoms and others could be explained as effects of infrasound, as well as constant humming and vibrations. The National Institutes of Health and Medicine recommends **a distance of three kilometers (1.86411 Miles) from the nearest turbine, for serious health effects to be avoided.** The proposed windmill affects numerous residents in this case. If such should occur who will be responsible for the health issues of the citizens?

Property Value Consideration

1. According to Michael McCann Appraisal and John Gordan Real-estate in a Forbes article "Do Wind Turbines Lower Property Values?" discussed that "they do have a negative impact on property value and make it harder to sell. Interesting many on the surface like the way they look from afar, though those same individuals frequently have the ""Not in My Backyard" (NIMBY) syndrome due to wind farms flicker, noise, health problems for humans and animals, and are seen as visual intrusions." Their impact on property values, especially as wind power grows, is increasingly concerning because a rapid decrease is occurring when development of these is too close to residents.

Financial Considerations

1. According to the article in the Daily Sentinel "Town closely examining potential impacts of wind turbine", the **Town of Florida in Montgomery County** indicated the New Leaf Energy changed its name from Borrego Solar. Why did the name change and has this occurred before? The concern of their stability may be in question when a sub enterprise has been established and can allow for an easy "departure" of that company if needed. Has the City of Oneida inquired on public recorded concerns from the Town of Florida in Montgomery County in reference to New Leaf Energy and their proposed planned?

Thank you for your consideration in having the contractor and owner of the land respond to these questions to obtain full disclosure for the next meeting.

V/r

Dr. Michael Evans
1078 Sugar Maple Drive, Oneida, New York 13421
mevans@eacc-services.com
315.729.9392

The form below has been submitted to all abutting property owners. Responses and/or proof of mailing will be provided to the City prior to a public hearing date.

Statement from Adjoining Property Owner

To be completed by the Petitioner

Owner:
Oneida Wind 1, LLC. c/o New Leaf Energy

Project address:
~~0 Brewer Road~~ 4949 Forest Ave – Parcel 46-2-42.3

Requested variance:
Construction of a 560-foot (total height) wind turbine rather than a 450-foot turbine allowed under the City Ordinances.

I certify that the plans presented to the undersigned neighbor for his/her review are identical to those plans for which an Area Variance is being requested. *

[signature] Brandon Smith, New Leaf Energy, Applicant 3/21/2023

Signature of Owner Date

To be completed by the Neighbor

Name: Michael Evans

Address: 1078 Sugar Maple Drive, Oneida, New York 13421

I have reviewed the above request for an Area Variance.

- ☐ I have no objection to the above request.
- ■ I object to the above request.

[signature] July 20, 2023

Signature Date

*Please Note: For ease of viewing, a single plan sheet has been included. PDF or paper copies of the full engineering plan set are available by contacting Brandon Smith at bsmith@newleafenergy.com or calling 978-221-3093