Anne-Sophie EVRARD
Researcher
(Univ Eiffel/TS2/Umrestte)

David ECOTIÈRE
Researcher
(Cerema-Univ Eiffel/Umrae)

OFATE Conference
March 9th, 2022

Noise emissions from wind turbines and human health: what is the impact ?

Université Gustave Eiffel

Cerema
CLIMAT & TERRITOIRES DE DEMAIN

Gustave Eiffel University

- Founded on 1st January 2020, from the fusion of the University of Paris-Est Marne-la-Vallée and the IFSTTAR national research institute
- A French university specialized in the study of cities and transportation
- UMRESTTE: Epidemiological Research and Surveillance Unit in Transport, Occupation and Environment

Cerema

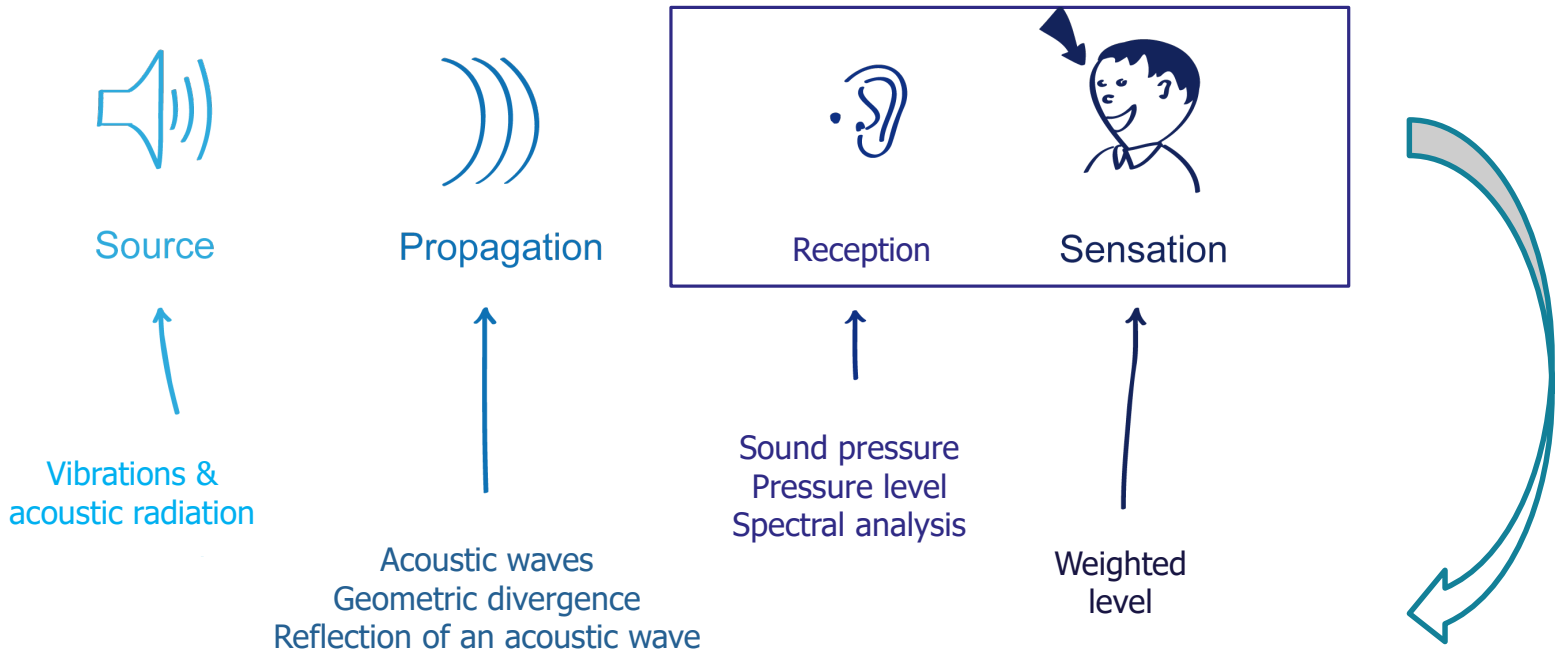
- Founded on 1st January 2014, from the fusion of 11 public technical establishments
- French public agency (2600 people) for urban planning, regional cohesion, ecological and energy transition for resilient and climate-neutral cities and regions
- UMRAE: Joint Research Unit on Environmental Acoustics (https://www.umrae.fr/)

umr ae

Cerema
CLIMAT & TERRITOIRES DE DEMAIN

Université Gustave Eiffel

From emission to perception



Health effects of noise

Auditory effects

Auditory fatigue,
hearing loss
(deafness), tinnitus,
hyperacusis

Non-auditory effects

Sleep
Cardiovascular system
(↑ blood pressure, hypertension,
ischemic heart disease)
Endocrine system
(↑ cortisol and catecholamines)
Mental health
(depression, anxiety, mental disorders)

Biological effects

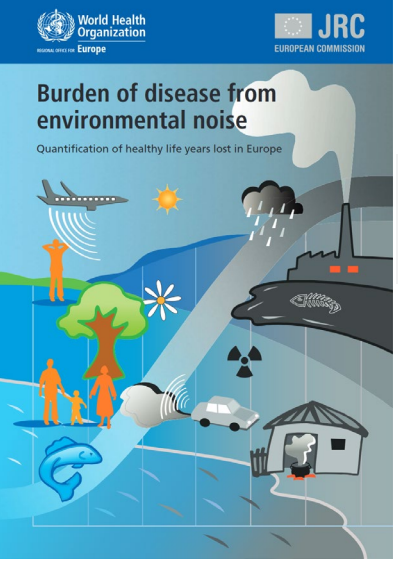
Annoyance, fatigue,
irritation, difficulty in
concentration

Subjective effects

Cognitive performance
(learning, comprehension, memory,
attention, concentration)
Medical consumption
(medication, consultations,
hospitalization)

Behavioral effects

Cerema
CLIMAT & TERRITOIRES DE DEMAIN
Université
Gustave Eiffel



Key figures in Europe

At least one million healthy life years are lost every year from traffic related noise in the western part of Europe (WHO, 2011)

Sleep disturbance

903 000 years

Tinnitus

22 000 years

Cognitive impairment

45 000 years

Annoyance

654 000 years

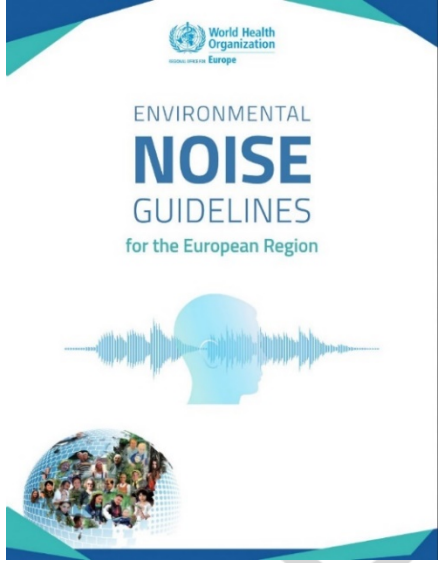
61 000 years

Ischaemic heart disease

Cerema
CLIMAT & TERRITOIRES DE DEMAIN

Université Gustave Eiffel

Health effects of transportation noise



- **Studies conducted after 2014**
  - Myocardial infarction, hypertension...
- **Insufficiently investigated health effects**
  - Hormone secretion
  - Psychological disorders (anxiety, depression) and mental health
  - Long-term effects of noise-related sleep disorders
  - Adverse pregnancy outcomes, fetal development, growth
  - Cancers

Health effects of wind turbine noise

Context (1)

- **Wind energy is expanding rapidly in France**, as elsewhere in the world
- Some people living near these installations are concerned about a significant **annoyance** that is sometimes **more severe** than would be expected from estimates and measurements of the acoustic field
- **Annoyance** often described as resulting **from infrasound (IS)**
- Acoustic pressure of the IS emitted by the wind turbines (WT) below the thresholds of perception. BUT **inaudibility of IS does not preclude action on the inner ear or central nervous system**
- **Evidence for health effects of WT noise either non-existent or of low quality** (Anses 2017, WHO guidelines 2018)
  - To date, **few epidemiological studies** have investigated the effects of audible noise from wind turbines and most of them show **methodological limitations** that make their results controversial
  - However, **none** of these studies specifically addressed **the health effects of IS or low frequency sound (LFS) emitted by WT**

Cerema CLIMAT & TERRITOIRES DE DEMAIN — Université Gustave Eiffel

Context (2)

- **Van Kamp and van den Berg (2021) reviewed the literature published between 2017 and mid-2020**
  - **Annoyance** again came forward as the most important consequence of sound: the louder the sound (in dB) of WT, the stronger the annoyance
  - Results of **scientific research for other health effects** (sleep disturbance, cardiovascular disease, metabolic effects, mental and cognitive impacts) are either **not available or inconsistent**
- **The WHO and the Anses (the French Agency for Food, Environmental and Occupational Health & Safety) therefore recommend to carry out epidemiological studies**
  - On a **large number** of individuals
  - Using **objective measurements** of the health status of participants
  - And **measuring WT noise exposure** with an objective and standardized approach over a wide range of levels and frequencies (including LFS)

Cibélius: Knowing the Impact of Wind Turbine Noise on Health (2017-2019)

- A number of issues remained to be overcome before such a study can be conducted in France
  - **The estimation of exposure to WT sound**: no real consensus on a WT sound prediction model
  - **The count of the number of people** exposed to different and contrasting WT sound levels
- **Cibélius: Knowing the Impact of Wind Turbine Noise on Health**
  - Feasibility study funded by Anses (2017-2019)

Cerema CLIMAT & TERRITOIRES DE DEMAIN
Université Gustave Eiffel

Wind turbine noise exposure of the French population

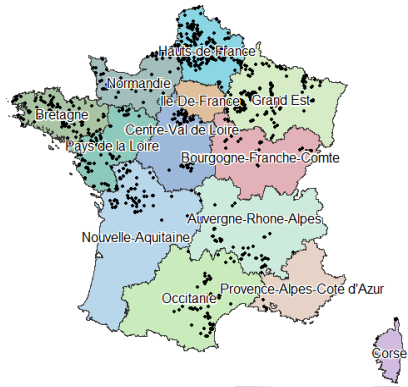
- **Public health issue = Exposed population x Health impact**

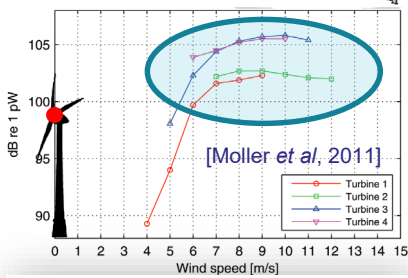
  Cibélius: evaluation of population exposure (RIBEolH project: health impact)

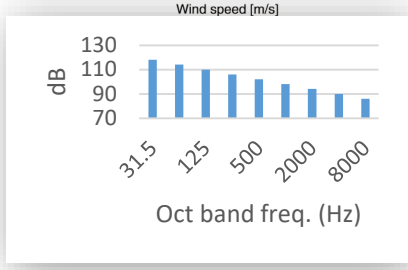
- **Data**
  - Wind farms: www.thewindpower.net (2017) + IGN
  - Population: MAJIC (2017)

- **Methods**
  - **Source emission**
    - WT: point source
    - Noise power: nom. operating of WT (max noise)
    - linear spectrum -4dB/oct (Moller et al., 2011)
  - **Noise propagation**
    - Harmonoise model + Cadnaa© software
    - Max of 8 wind directions, 2 typ. Meteo class (Day, Night), soft ground

-> NB: overestimation of noise exposure

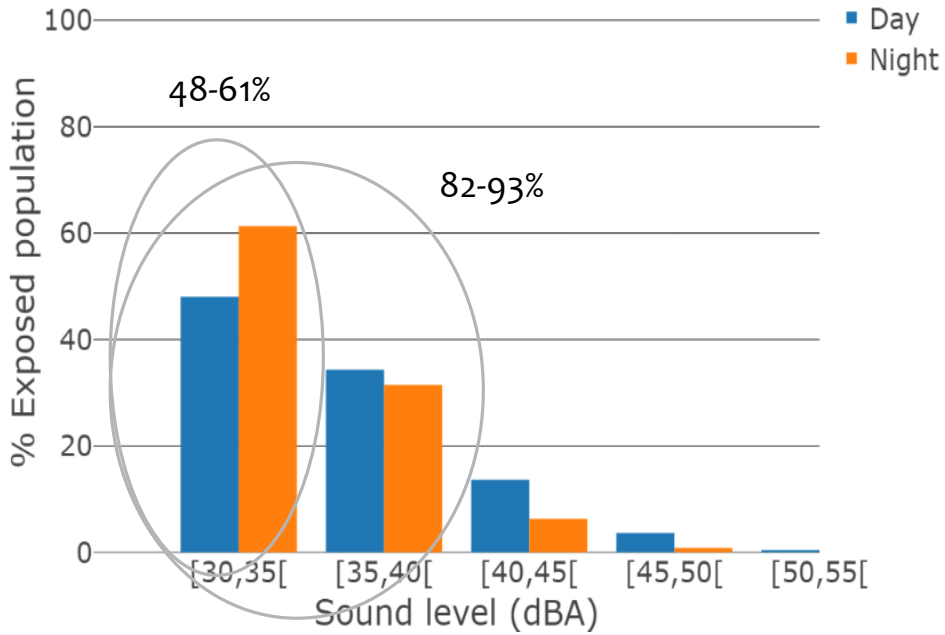






Wind turbine noise exposure of the French population

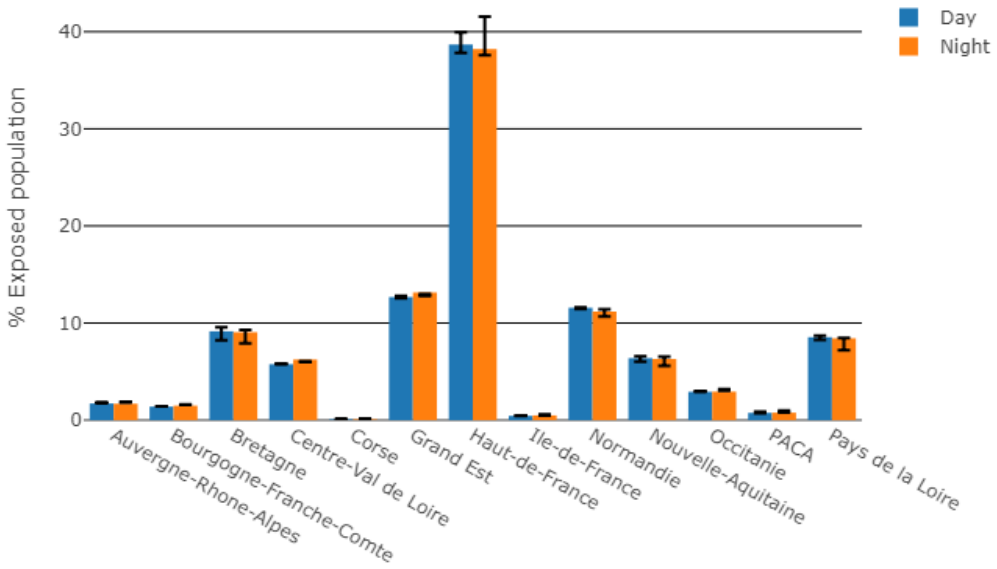
- **Results**
  - **People exposed to WT sounds levels above 30 dBA**
    - Day: 685,770 (1% of the French population in 2017)
    - Night: 721,559 (1% of the French population in 2017)
  - **Moderate noise exposure levels**
    - 82-93% of exposed population are exposed to levels lower than 40dBA

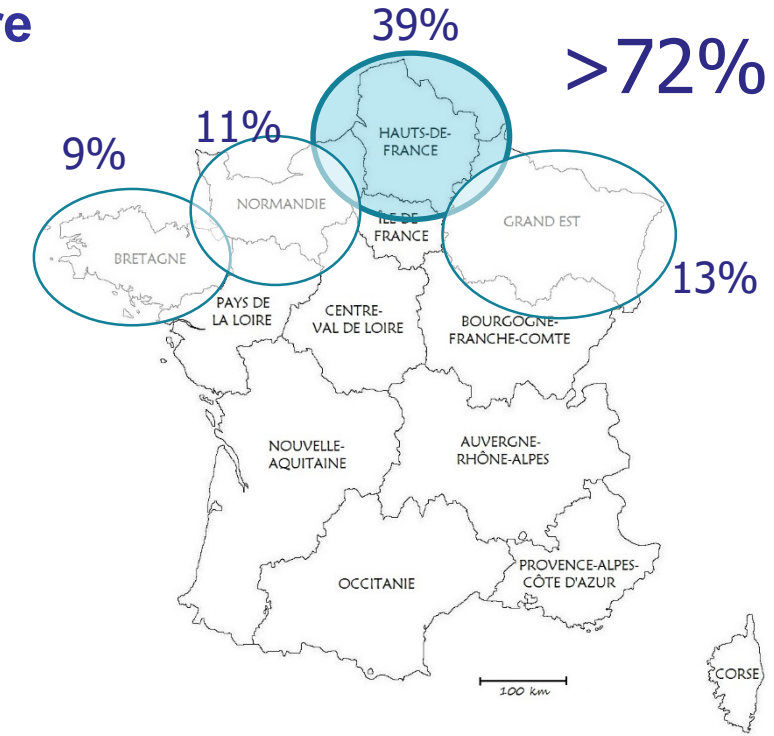


Cerema CLIMAT & TERRITOIRES DE DEMAIN
Université Gustave Eiffel

Wind turbine noise exposure of the French population

- **Results: regional distribution of population exposure**
  - ➢ North France: more than 72% of exposed people
    - Hauts-de-France: 39%
    - Bretagne, Normandie, Grand-Est: 9-13%

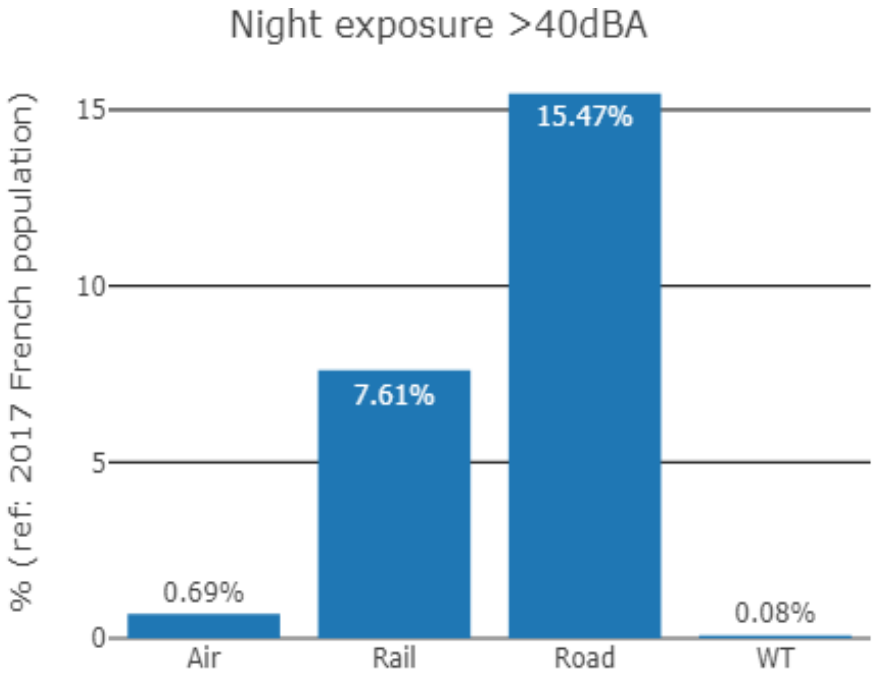




Cerema CLIMAT & TERRITOIRES DE DEMAIN
Université Gustave Eiffel

Wind turbine noise exposure of the French population

- **Results: comparison with other environmental noise sources exposure**
  - People exposed to levels above 40 dBA at night
    - Road: 15.5% of the French population in 2017
    - Rail: 7.6%
    - Air: 0.7%
    - Wind Turbines: 0.08%



More details

Ecotière *et al*, 2022. Quantification of Sound Exposure from Wind Turbines in France. International Journal on Environmental Research and Public Health 19, 23. https://doi.org/10.3390/ijerph19010023

Cerema CLIMAT & TERRITOIRES DE DEMAIN

Université Gustave Eiffel

RIBEolH: Research on the impacts of wind turbine noise on humans: sound, perception, health (2020-2024)

RIBEolH

- **Objectives**
  - **To evaluate the health effects** (effects on the cochleo-vestibular system, sleep disturbances, stress, cardiovascular diseases, psychological disorders and annoyance) of audible noise, in particular LFS, but also of IS, emitted by WT
  - **To better understand the auditory mechanisms associated with the perception of IS and LFS from wind turbines**, and more particularly the perception of sound intensity (loudness) and amplitude modulations, and their association with annoyance
  - **To better understand the effects of IS on the inner ear or central nervous system**, which may explain some of the symptoms sometimes described by people exposed to IS and who complain about them

PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR
ANR

Cerema CLIMAT & TERRITOIRES DE DEMAIN
Université Gustave Eiffel

RIBEolH: Research on the impacts of wind turbine noise on humans: sound, perception, health (2020-2024)

RIBEolH

- **Methods: two studies**
  - **Epidemiological study (1,200 residents of wind farms in France)**
    - ✓ Exposure to audible noise, in particular LFS, and IS, emitted by WT **Harmonoise model for noise prediction**
    - ✓ **Experimental campaign** on a wind farm site to validate synthesized sounds and to provide sound samples for psychoacoustic and physiological tests
    - ✓ **Questionnaire**: annoyance, noise sensitivity, sleep disturbance, medication use, health status (including hypertension, cardiovascular pathologies and psychological distress)
    - ✓ Blood pressure and heart rate **measurements**
    - ✓ **Cortisol** measurement (stress)
    - ✓ (Recordings of objective sleep quality (Eolsomnie, 100 residents))

PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR

Cerema CLIMAT & TERRITOIRES DE DEMAIN

Université Gustave Eiffel

RIBEolH: Research on the impacts of wind turbine noise on humans: sound, perception, health (2020-2024)

RIBEolH

- **Psychoacoustic and physiological study in laboratory (about 150 listeners)**
  - ✓ **Sound synthesis** by a physical model for different WT operating conditions
    As a good sound quality of the recordings is only possible *in situ* for low wind speeds not all annoying sensations due to WT noise can be studied from recorded sounds
  - ✓ **Perceptual validation** of the synthesized sounds by comparing them to sounds recorded under the same operating conditions of the WT
  - ✓ Determination of **a loudness model** applicable to LFS and IS
  - ✓ Analysis of the main **acoustic annoyance factors** and suggestion of associated indices
  - ✓ **Physiological measurements** of cochleo-vestibular responses before and after strictly controlled sound exposure

[Oerlemans et al. 2007]

PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR
ANR

Cerema CLIMAT & TERRITOIRES DE DEMAIN

Université Gustave Eiffel

References

WHO. Burden of disease from environmental noise. Quantification of healthy life years lost in Europe. Bonn, Germany: 2011.

ANSES. Évaluation des Effets Sanitaires des Basses Fréquences Sonores et Infrasons dus Aux Parcs Eoliens, Saisine 2013-SA-0115: Avis de l'ANSES; Collective Expertise Report; French Agency for Food, Environmental and Occupational Health & Safety: Paris, France, 2017.

WHO. Environmental Noise Guidelines for the European Region; World Health Organisation: Copenhague, Denmark, 2018.

Van Kamp I, van den Berg F. Health effects related to wind turbine sound: An update. Int. J. Environ. Res. Public Health 2021, 18, 9133.

Ecotière D, Demizieux P, Guillaume G, Giorgis-Allemand L, Evrard AS. Quantification of Sound Exposure from Wind Turbines in France. Int. J. Environ. Res. Public Health 2022, 19, 23.

Anne-Sophie EVRARD

anne-sophie.evrard@univ-eiffel.fr

David ECOTIÈRE

david.ecotiere@cerema.fr

Université Gustave Eiffel

Cerema
CLIMAT & TERRITOIRES DE DEMAIN