RES & BESS Workshop

Ministry for Energy and Environment

Wind Energy and the Environment: impacts and how to mitigate them

Andreas Vlamakis

With contributions from: Ioanna Eleftheriou, Sevie Dima (data analysis & maps)

27 April 2026

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- ❑ Characteristics of wind farms
- ❑ Categorization of Impacts

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Foundations and platforms

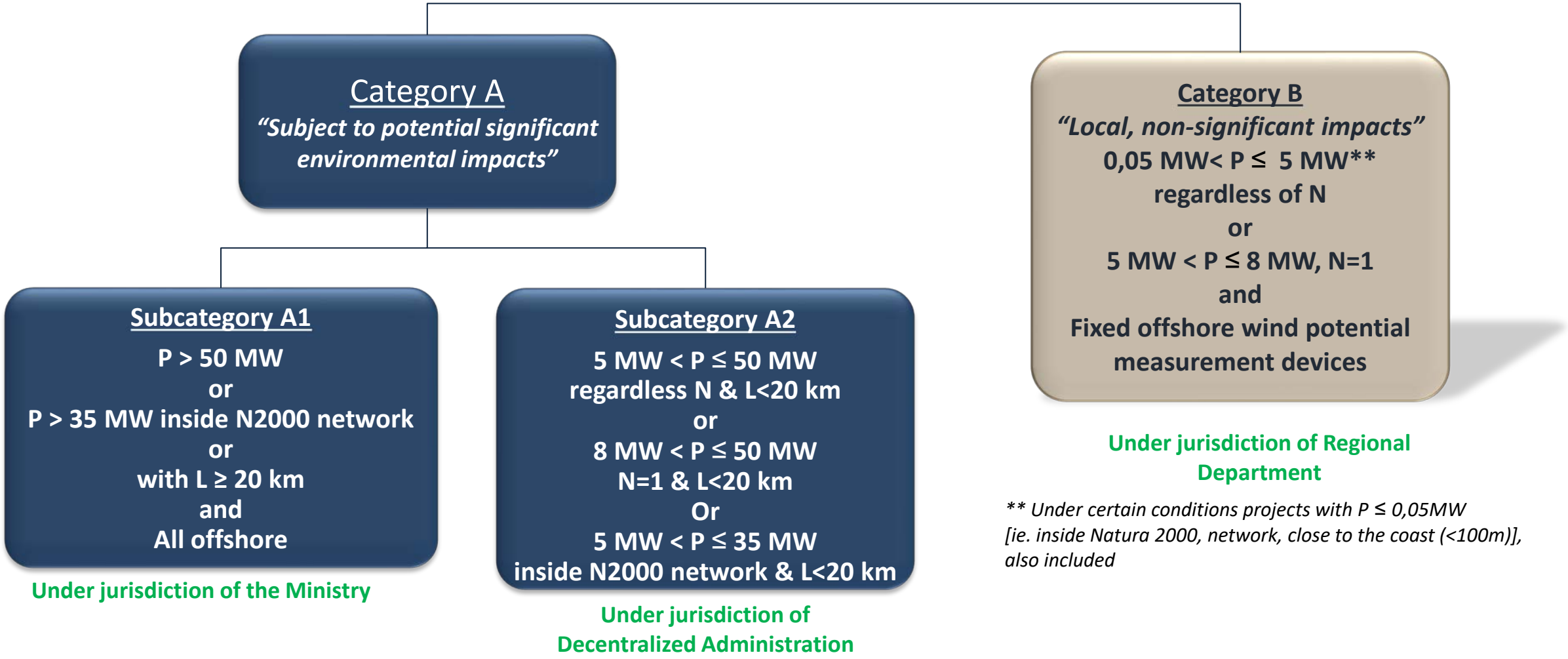
WTG foundation construction phases

Final terrain formation of the platform

Roads & electrical infrastructure works

- Access roads & Internal roads:
  - modifications on existing roads
  - new dirt roads according to forestry legislation
- Interconnection works:
  - Substations
  - underground & overhead power cables
  - control rooms etc.

Wind Farms: Environmental Impacts classification*



*** Under certain conditions projects with P ≤ 0,05MW [ie. inside Natura 2000, network, close to the coast (<100m)], also included*

P: installed capacity (MW)
L: overhead interconnection line length (HV ≥150kV), km
N: Nr of WTG

** Ministerial Decision, Nr. 63951/4418/2024 (Government Gazette 3867 B)*

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Greece’s special characteristics:

- ❑ Complex terrain
- ❑ High wind potential
- ❑ Rich biodiversity

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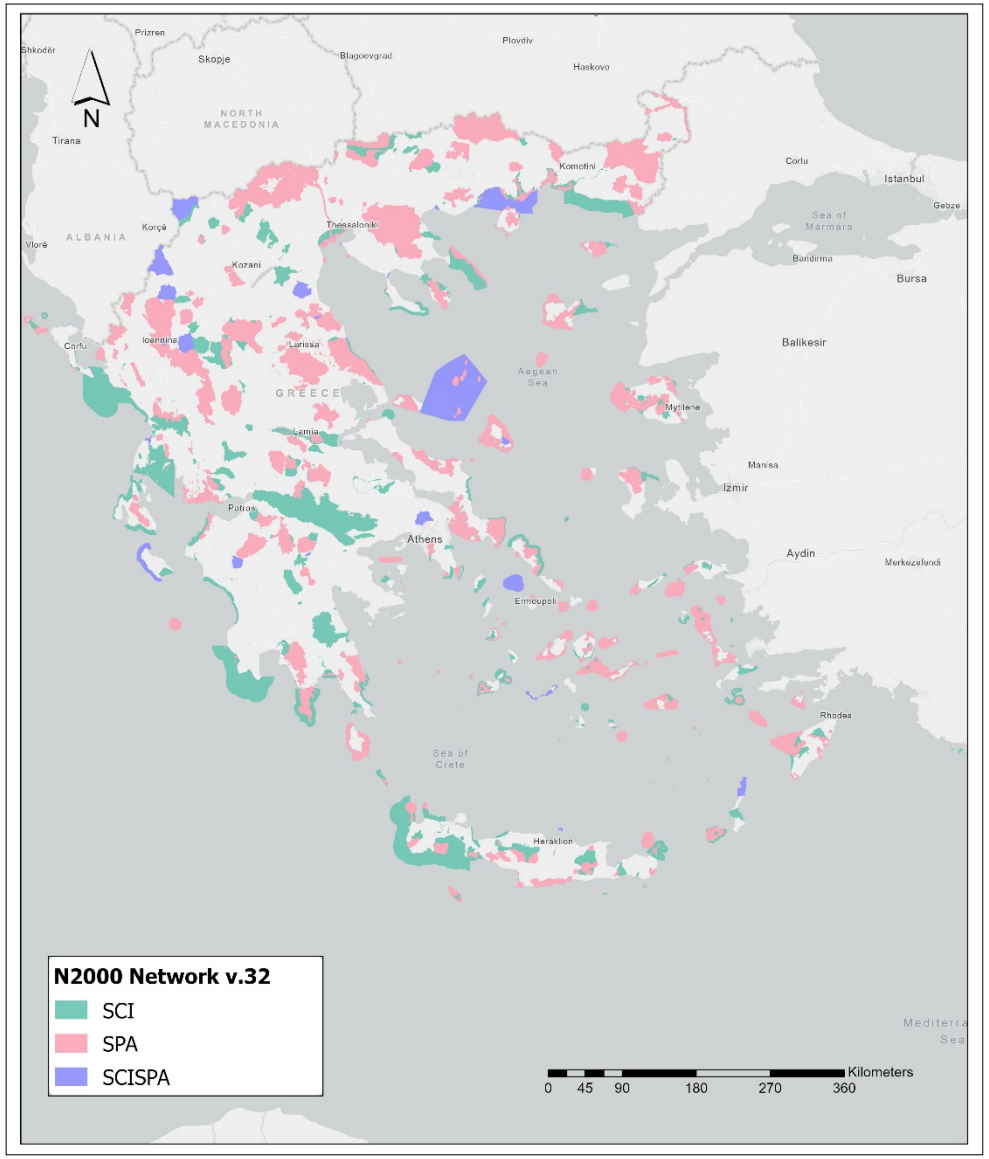
Natura 2000 Network in Greece



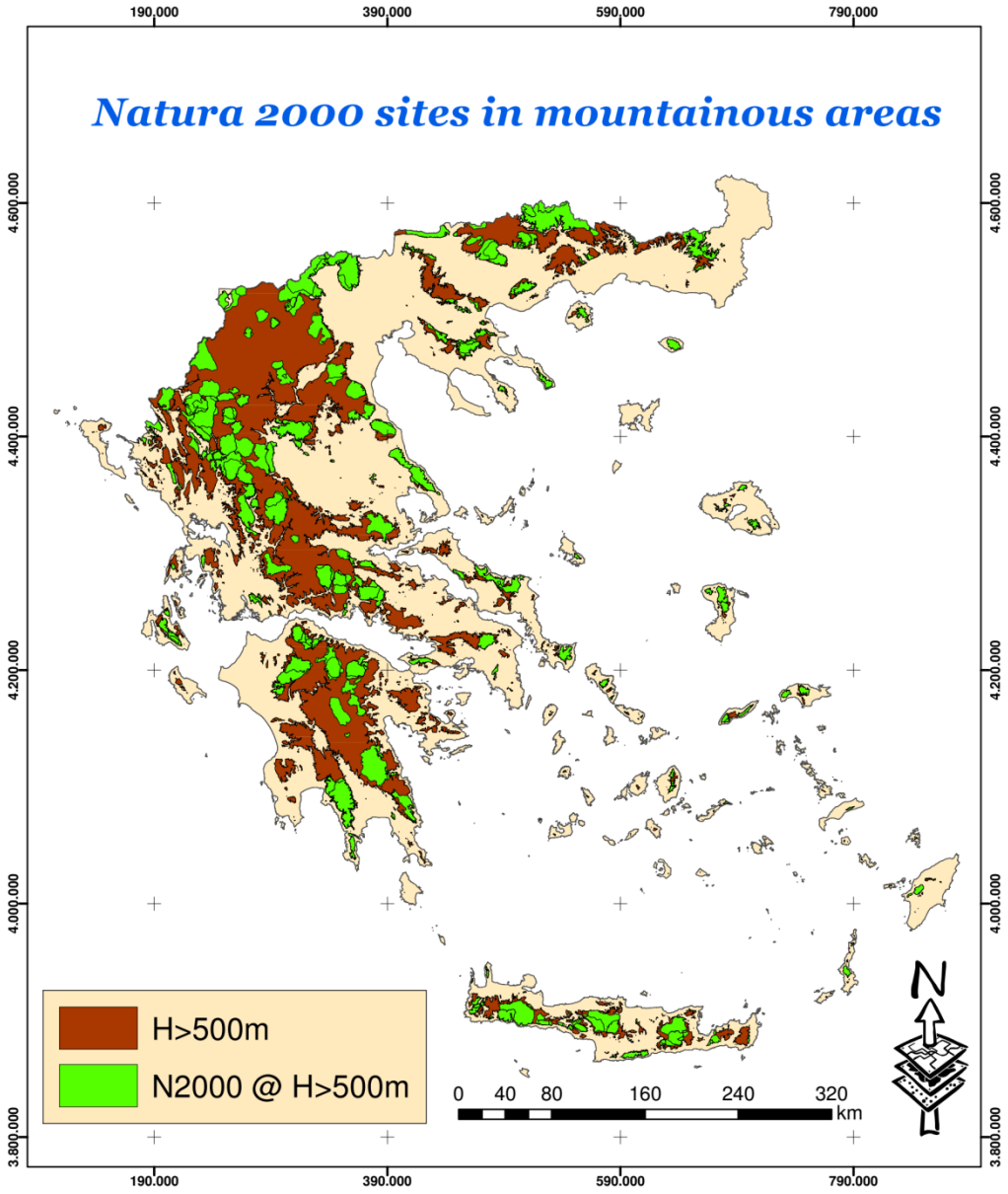
>27% of the country's terrestrial area

265 SCIs + 207 SPAs → 446* sites

Source: https://ypen.gov.gr/ & GG 4432/B/2017

** 26 sites are simultaneously SCIs & SPAs*

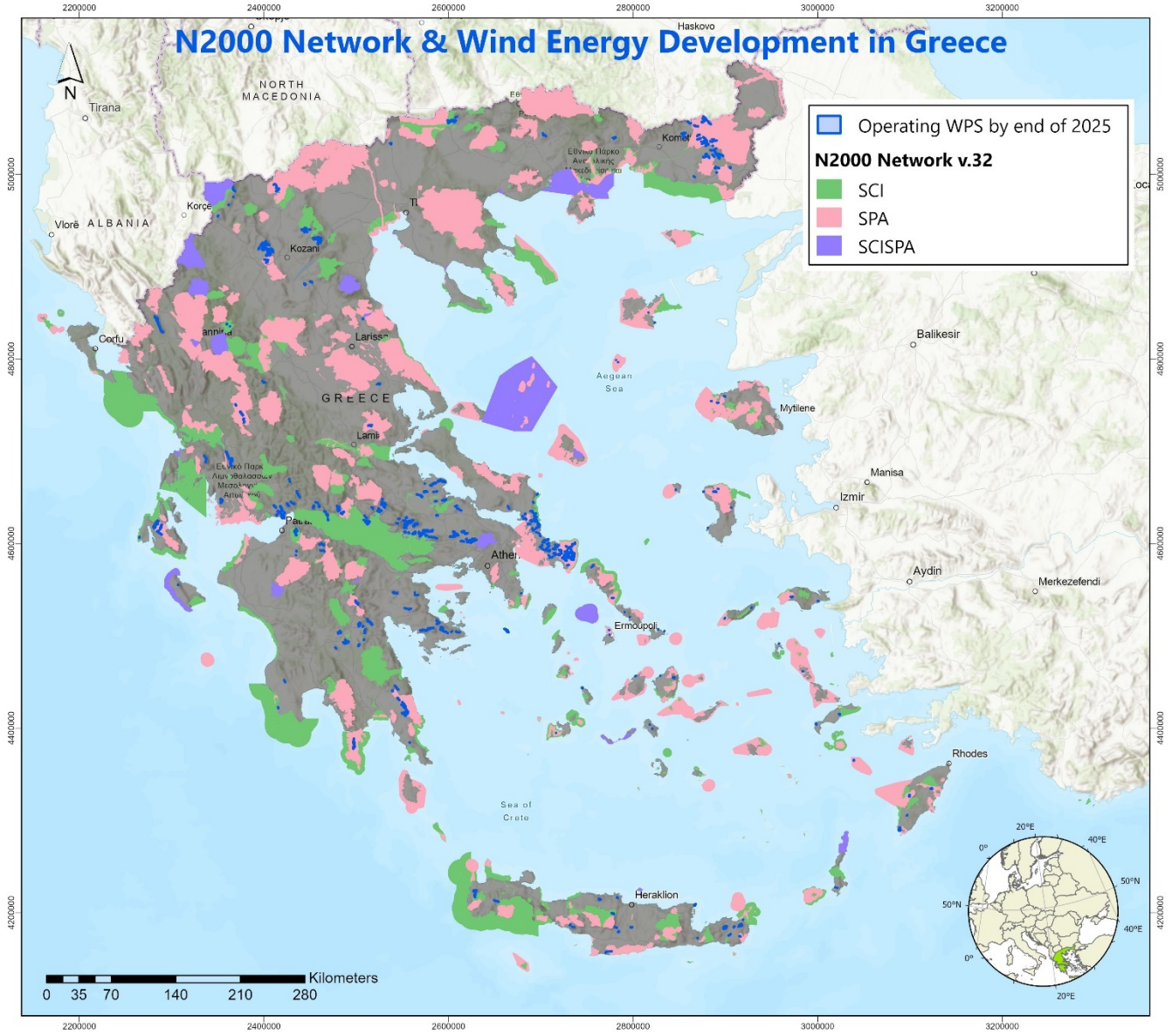
Natura 2000 Network: Focus on high altitudes



Focus on altitudes above 500 m

37,1%
coverage of the Natura 2000 Network

Wind Energy & Natura 2000 Network (operational projects)



Source: https://geo.rae.gr/, https://eletaen.maps.arcgis.com, 12/2025

5.695 MW
(3.093 WTGs)

30,3%
inside N2000
(1657,3MW-938WTGs)

- Annual environmental monitoring programs
- Review of environmental monitoring reports by the competent authorities
- Extensive database

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The footprint of wind energy

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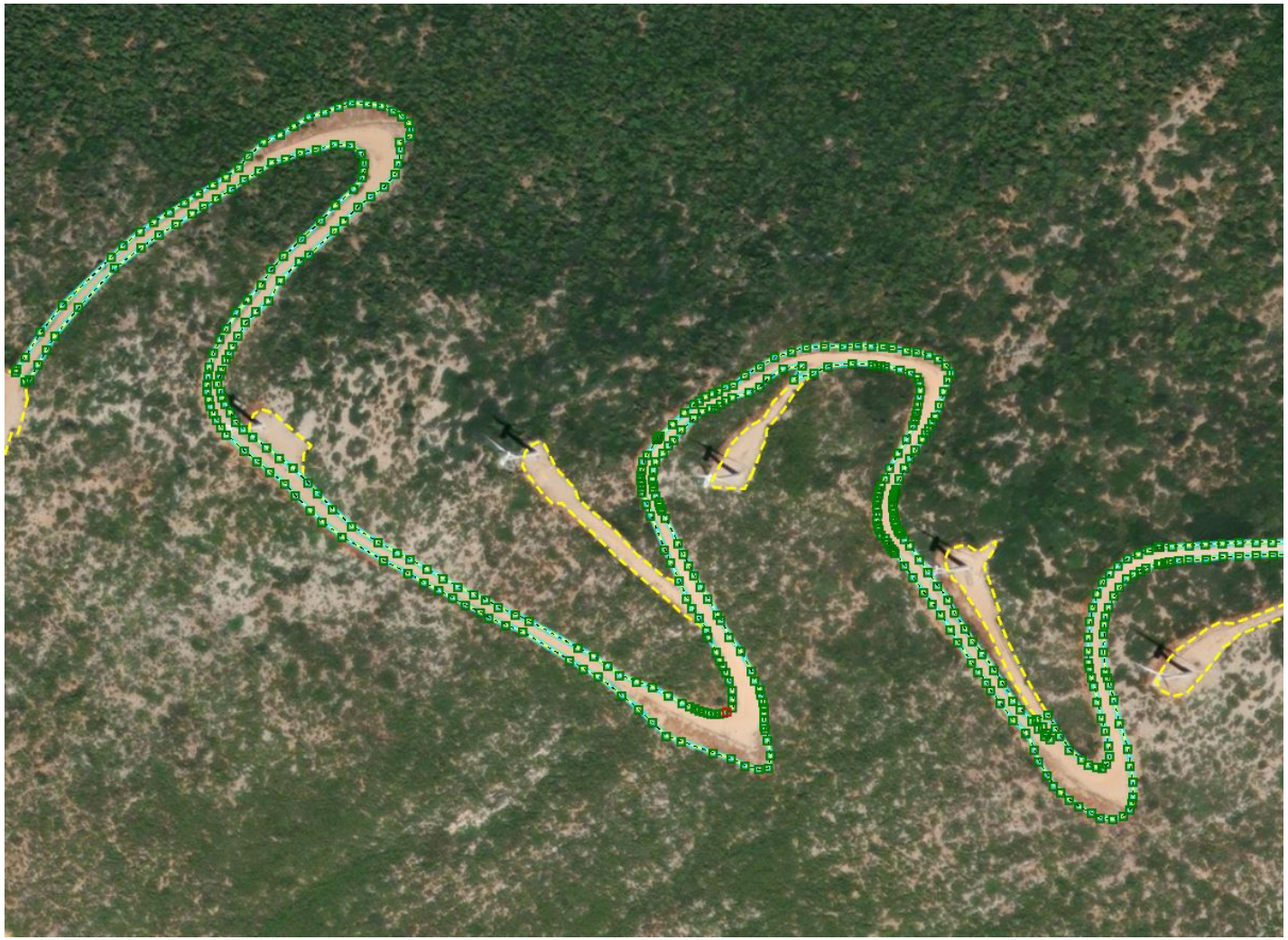
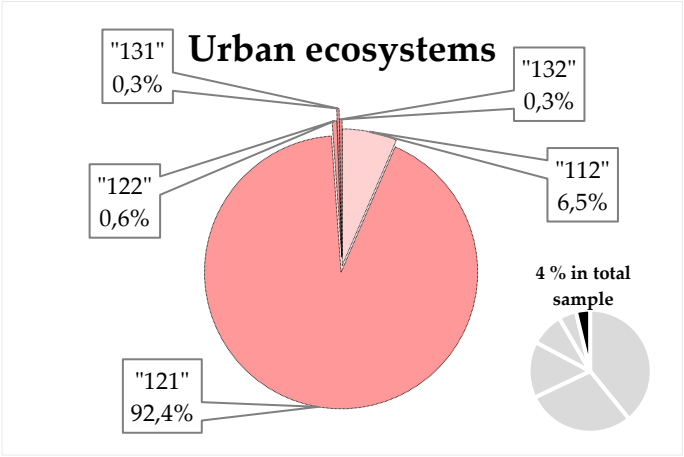
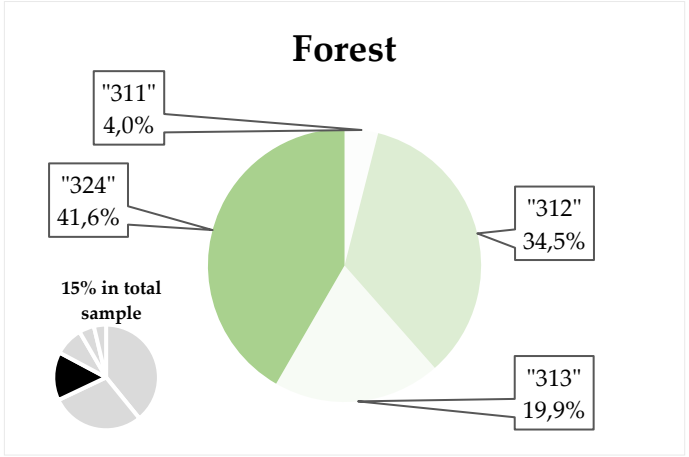
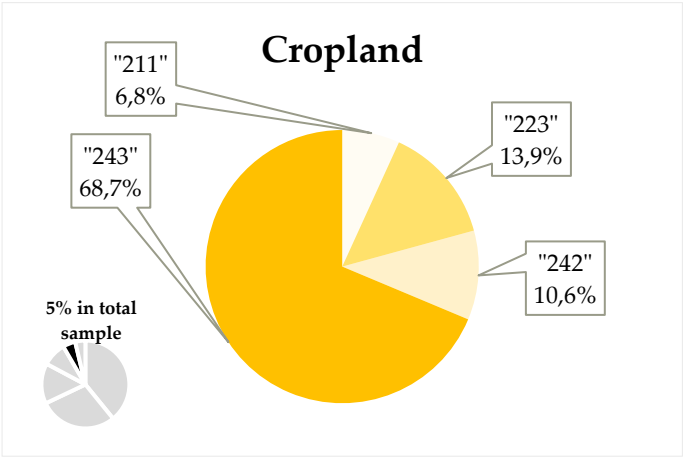
Estimating the footprint of wind energy in Greece [1]

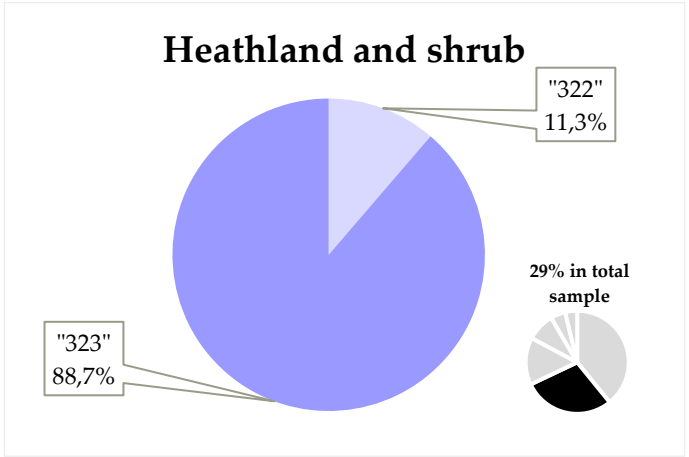
- Empirical analysis of **2.6 GW** of wind projects in Greece using GIS-based infrastructure mapping
- Very low land take observed: **~0.33 ha/MW** and **~1.58 m²/MWh** — among the lowest reported internationally

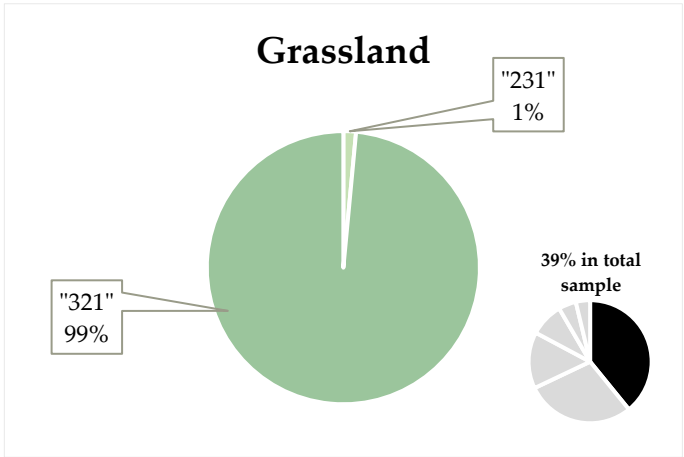


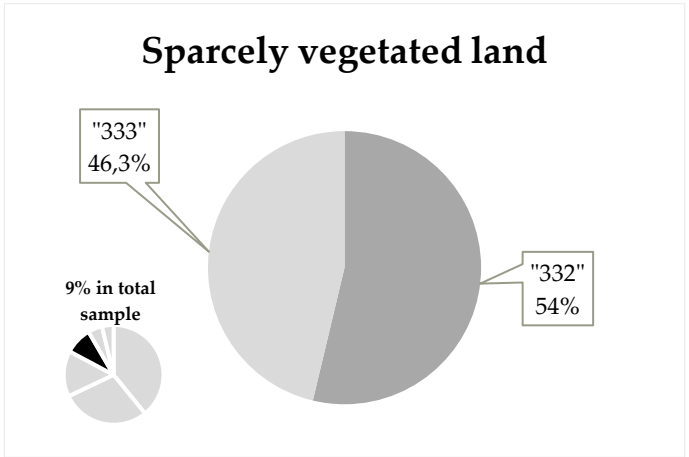










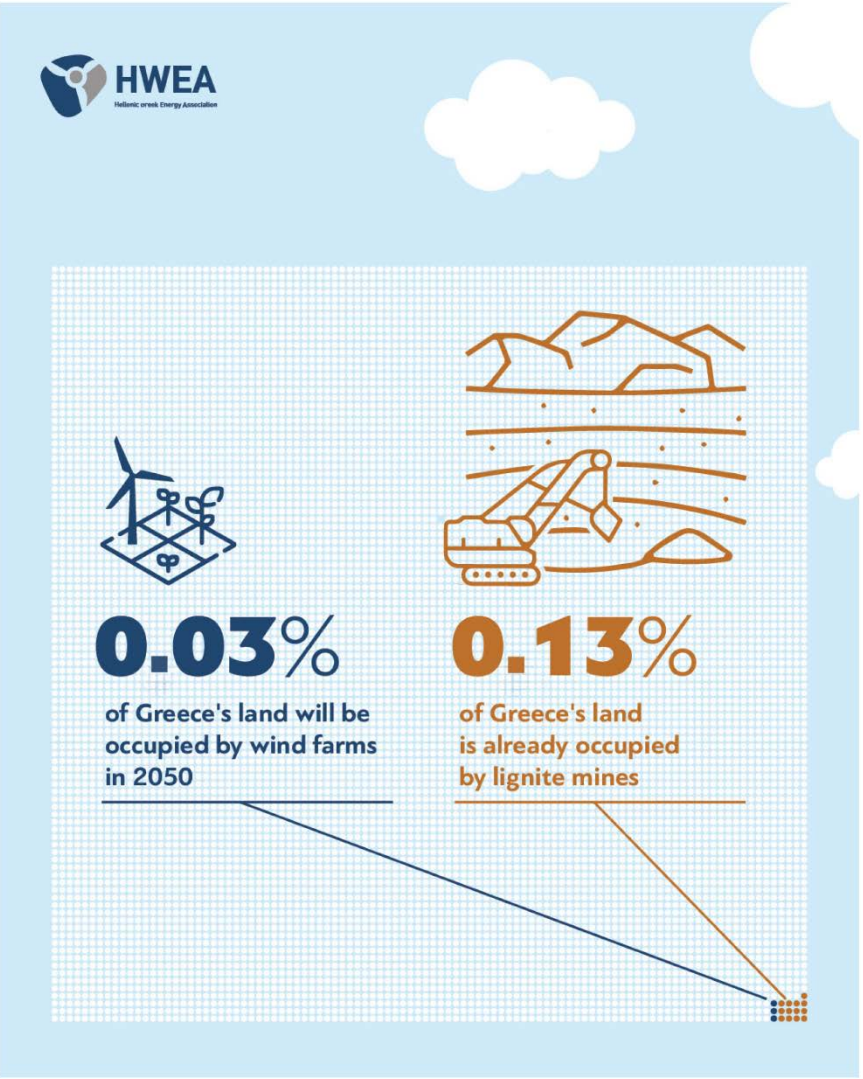


Estimating the footprint of wind energy in Greece [2]

Most common involved land covers:

- Natural Pastures 38,6% (CLC 321)
- Sclerophyllous vegetation 25,6% (CLC 323)
- Transitional forest-shrub areas 6,2% (CLC 324)

Wind energy has a small land footprint



- Lignite mines in the country have already transformed an area **x4** bigger than the one that will be required to achieve country's targets for 2050
- Land take alone is not a sufficient environmental indicator and should be assessed within a broader cost–benefit framework
- Land between turbines remains available for other uses (e.g. agriculture, grazing)

land

MDPI

Article

Beyond the Footprint: Empirical Land Use and Environmental Patterns of Wind Energy in Mountainous Landscapes

Andreas Vlamakis [1,2,*], Ioanna Eleftheriou [2], Sevie Dima [2], Efi Karra [1] and Panagiotis Papastamatiou [1,2]

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See our study here:
https://doi.org/10.3390/land15020344
and here:

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Mitigating impacts on birds and habitats

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Special care for avian fauna (SPAs- IBAs)

Legal framework covering 207 SPAs & 196 IBAs in Greece

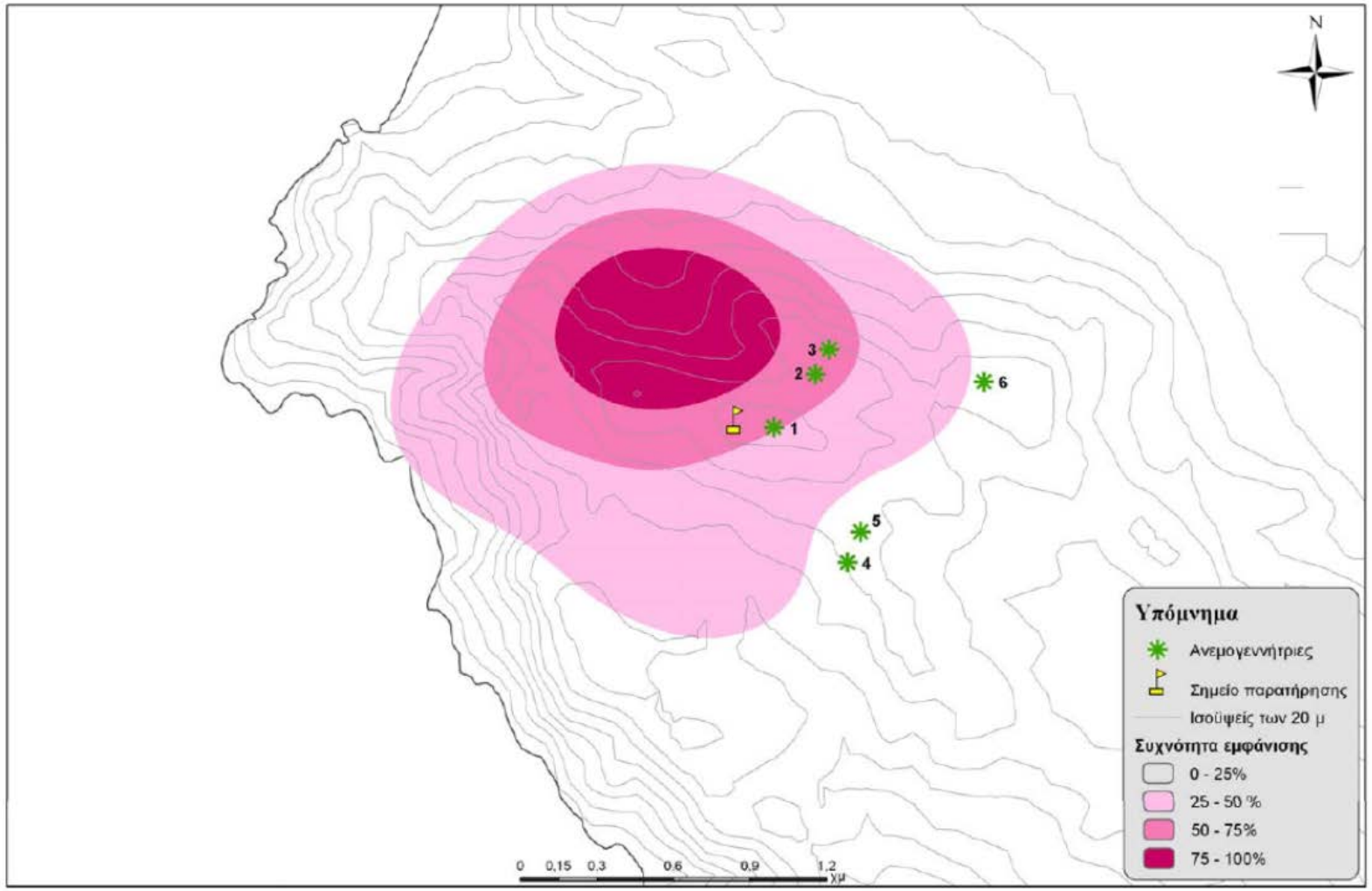
- Designation of **qualifying species** per site
- **Wind farm exclusion**:
  - Within SPAs overlapping Ramsar wetlands
  - + 3 km buffer zone (where buffer falls inside SPA)
- **Species-specific protection**:
  - Exclusion zones around nests for 21 qualifying species
- **Technical requirements**:
  - Underground cabling within SPAs
  - Automated turbine shutdown in migratory corridors
- **Mitigation measures**:
  - Removal of animal carcasses from turbine pads
  - Assessment of the need for installing acoustic and/or visual deterrent systems (based on proximity to cliffs, nesting and foraging areas)

Legal framework: MD 37338/2010 (GG 1495B) & MD 8353/2012 (GG 415B)

Extended field work before construction

- **≥1 year** field surveys (covering the full annual life cycle)
- Dedicated ornithological assessment (expert team)
- Exclusion zone delineation

Example: spatial distribution of a raptor species within the wind farm site



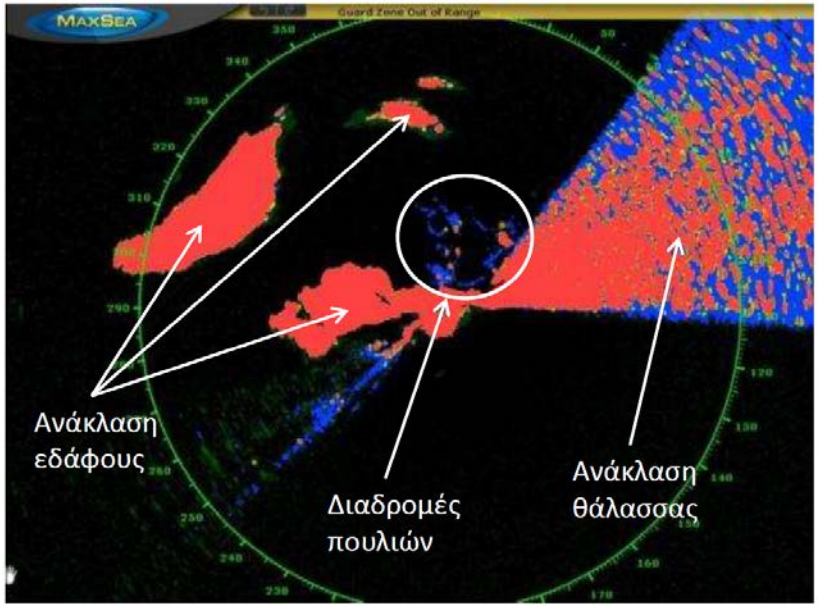
Advanced impact mitigation systems [1]

High-resolution cameras for tracking bird activity in the vicinity of wind turbines

Source: https://www.windfarms-wildlife.gr

Advanced impact mitigation systems [2]

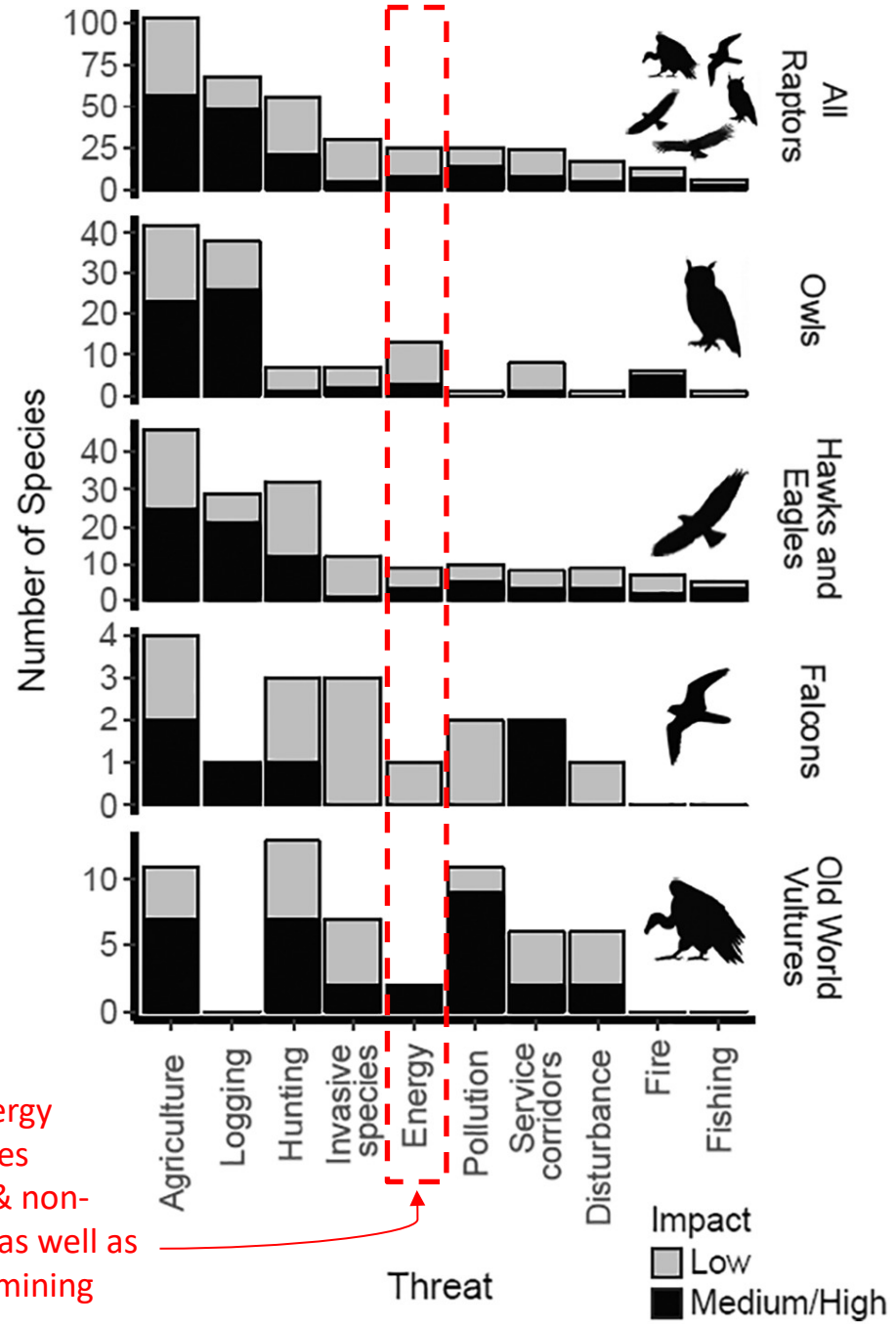
- Bat detectors
- Marine & meteorological radars
- Thermal cameras



Source: https://www.windfarms-wildlife.gr

Other impact mitigation measures

- **Habitat management** (vegetation clearance) around wind turbines to reduce raptor attraction
- Creation of **foraging areas** in adjacent zones
- Supplementary **feeding stations** for vultures away from wind turbines
- In extreme cases, **painting one turbine blade** to reduce collision risk



Includes all energy production types (conventional & non-conventional), as well as quarrying and mining activities

Comparison of threats to raptor species (global scale)

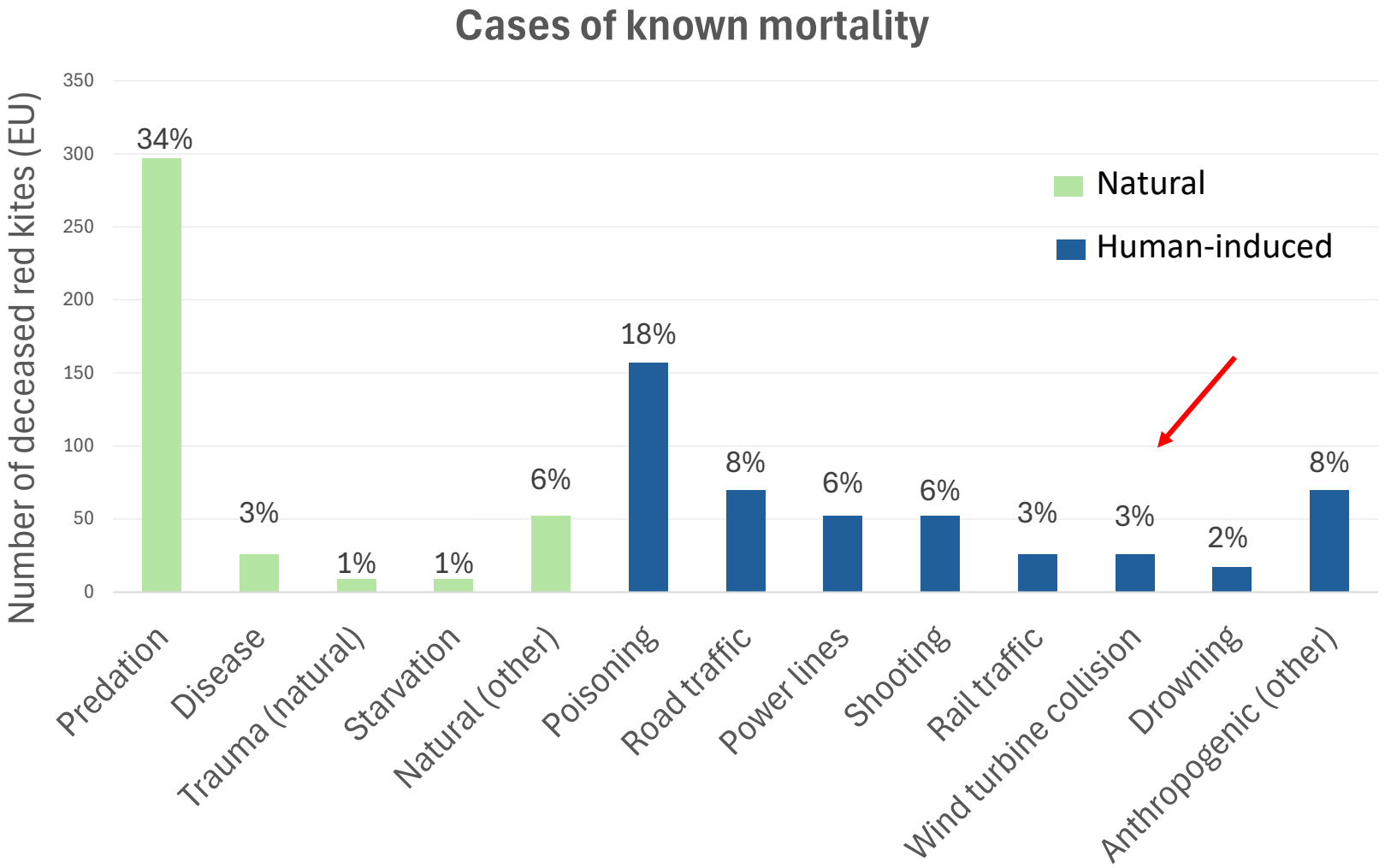
- Global assessment covering 557 raptor species
- Based on IUCN Red List data

Key findings

- Primary threats are agriculture, logging and hunting/trapping
- Energy production (incl. wind) affects fewer species
- Declines driven mainly by habitat degradation and poisoning

Source: State of the world's raptors: Distributions, threats, and conservation recommendations https://doi.org/10.1016/j.biocon.2018.08.012

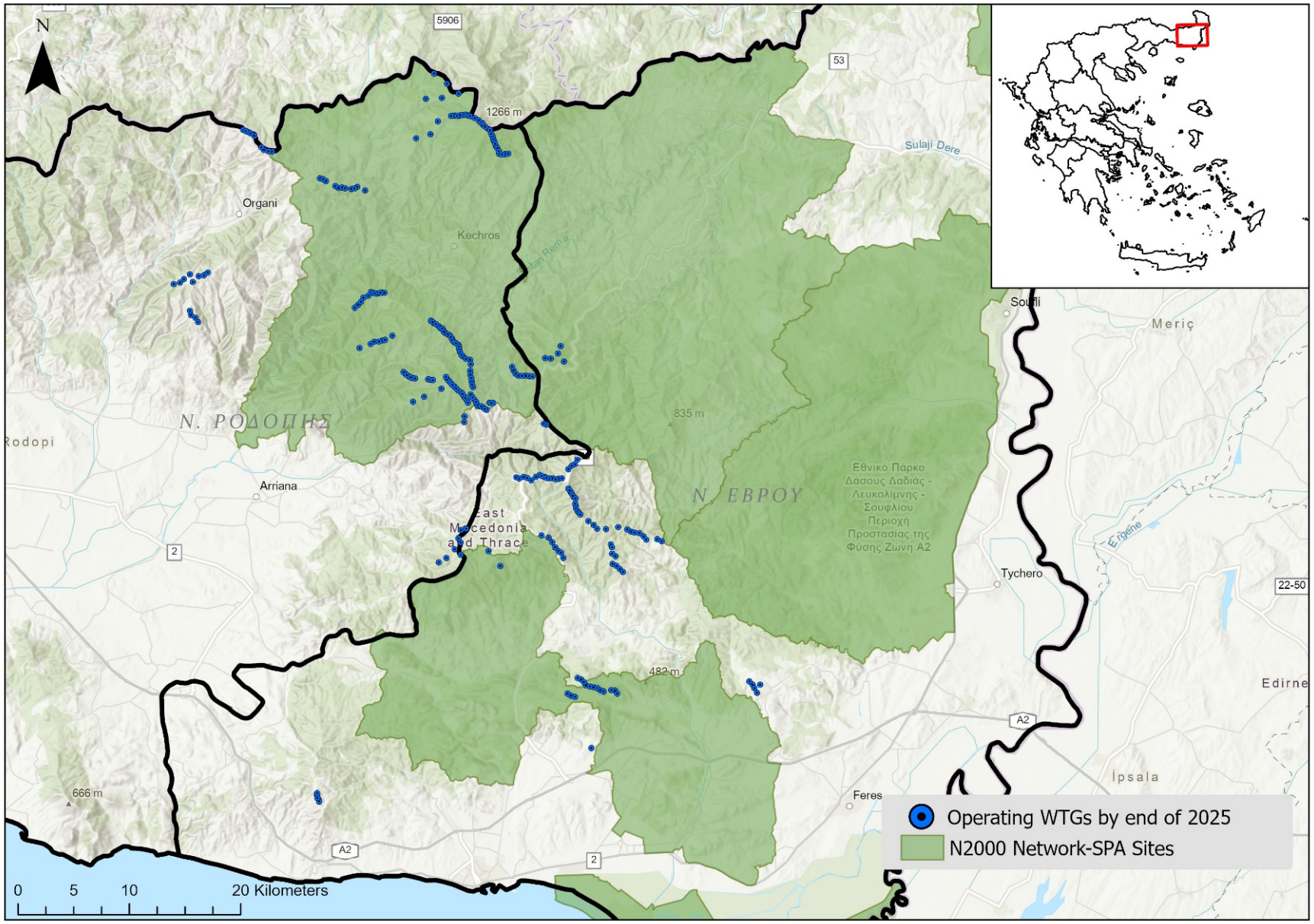
Comparison of threats to Red Kite (Milvus milvus)



- Pan-European study (14 countries)
- Period: 1/2013-12/2022
- Sample size: **2.346** tagged birds
- Mortality causes: 48 identified, grouped into 13 categories
- Cases with known mortality reason: **873**

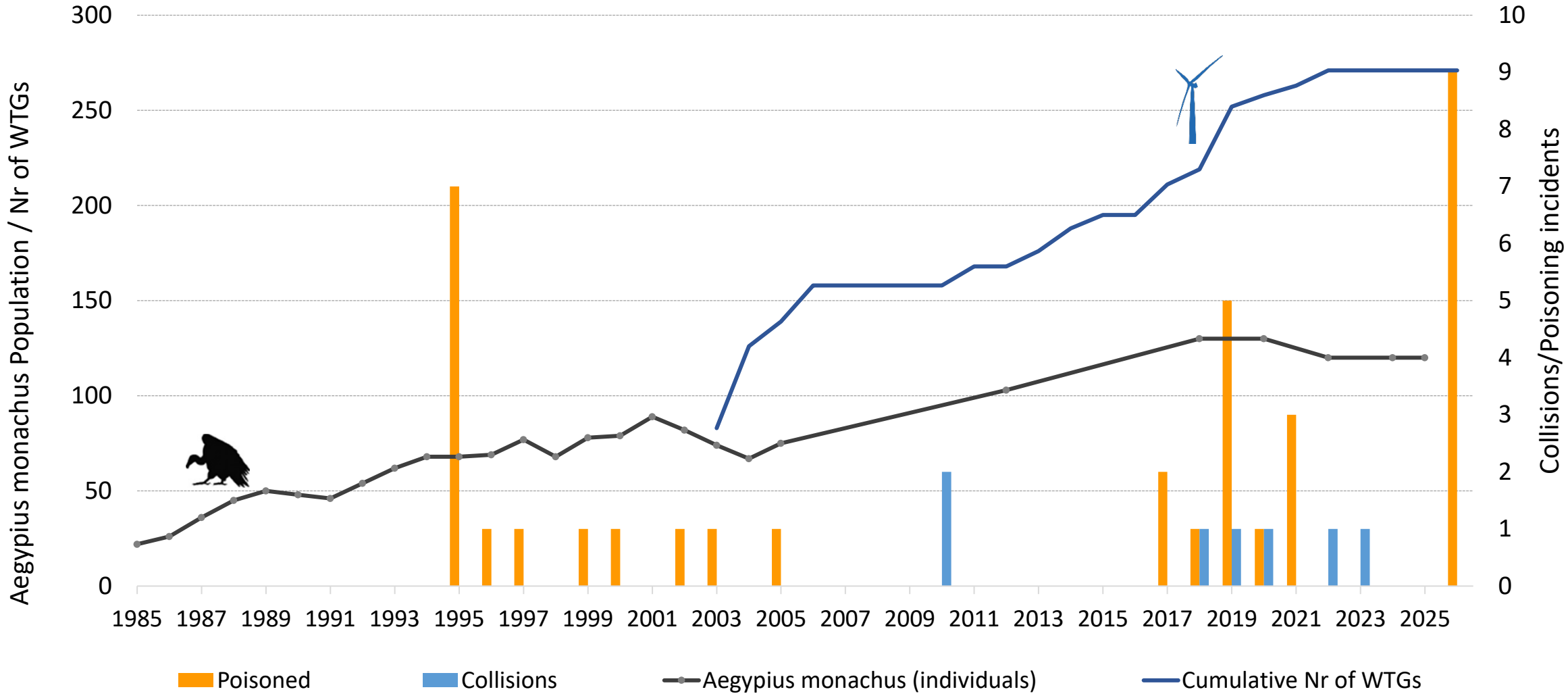
Source: LIFE EUROKITE Project (LIFE18 NAT/AT/000048) & reproduction of data from poster presentation “Investigating the main mortality reasons of the European Red Kite population by high-resolution GPS telemetry tracking” in CWW 2025

Case study in Greece: Thrace (NE Greece)



- Area with **high wind potential**
- Hosts the **last remaining colony** of Aegypius monachus (black vulture) in Greece

Findings from the case of Thrace

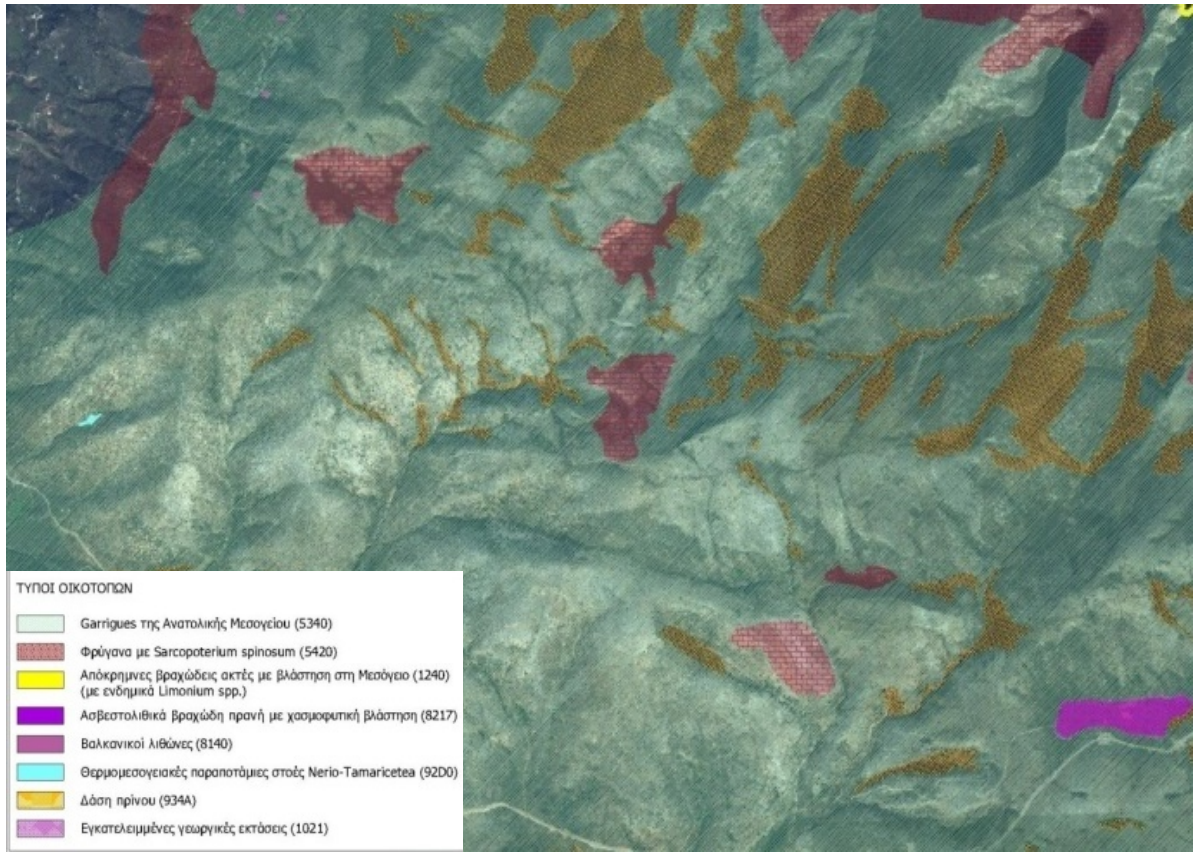


Sources

Population data: Skartsi et al. (2008); Vassilakis et al. (2016, 2017); Dimitriou et al. (2021); Sidiropoulos et al. (2022); Bounas et al. (2024, 2026); Bounas et al. (2025, technical report); Vulture Conservation Foundation; WWF Greece (2018), **Poisoning mortality:** Vlachos et al. (1999); Skartsi et al. (2008); HOS & WWF Greece annual reports on poisoned baits (2014–2022), **Collision data:** Society for the Protection of Biodiversity of Thrace, https://spbt.gr/downloads/, (update: 31.03.2026), **Wind capacity:** HWEA, Wind Statistics (2025), https://eletaen.gr/hwea-wind-statistics/

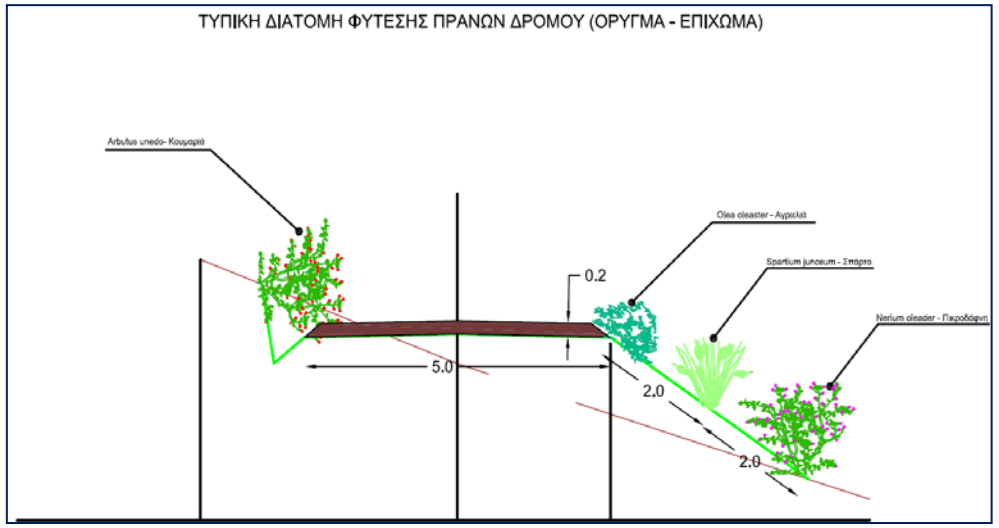
Habitat Types and Flora Species

- Habitat type mapping
- Endemic flora species
- Road design based on the above parameters
- Preventing habitat fragmentation
- Limit on total occupancy (e.g. <2%)

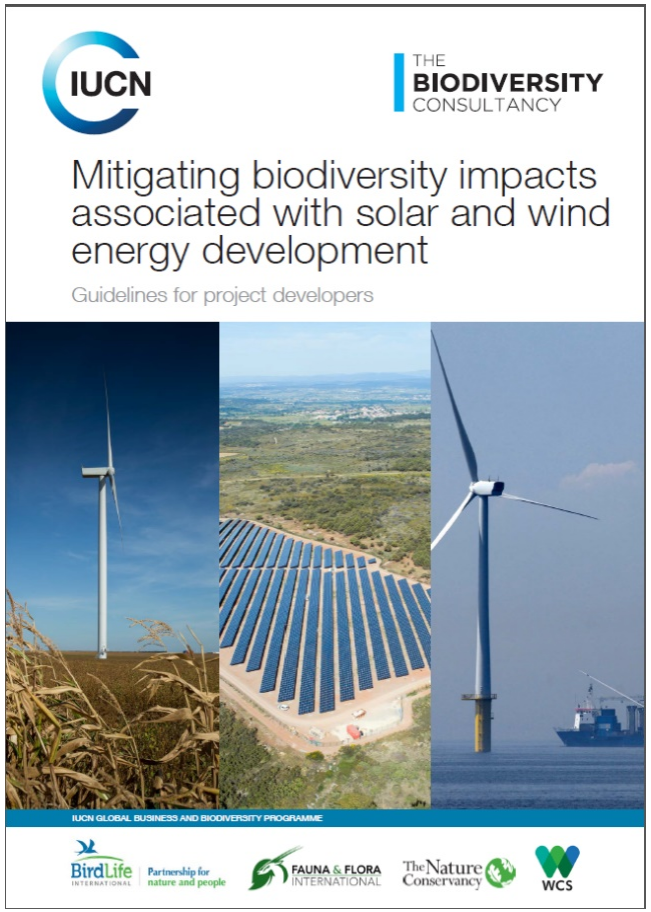


Restoration of interventions

- **Land restoration** in cuts and embankments through revegetation (under the guidance and supervision of the competent Forest Office)
- Management of excess excavated material
- **Maintenance plan** (3–5 years)
- **Reforestation** of an area equal in size to that of the interventions in an adjacent area



Good Practice Guidance: There is rich experience



1. Guidance document on wind energy developments and EU nature legislation, EC, 2020
2. Mitigating biodiversity impacts associated with solar and wind energy development. Guidelines for project developers, IUCN (https://doi.org/10.2305/IUCN.CH.2021.04.en)
3. Demonstration of good practices to minimize impacts of wind farms on biodiversity in Greece. LIFE12 BIO/GR/000554 https://www.windfarms-wildlife.gr

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Other issues:

- ❑ Repowering & Recycling
- ❑ Coexistence with cattle breeding
- ❑ Noise
- ❑ Visual effect
- ❑ Community benefits

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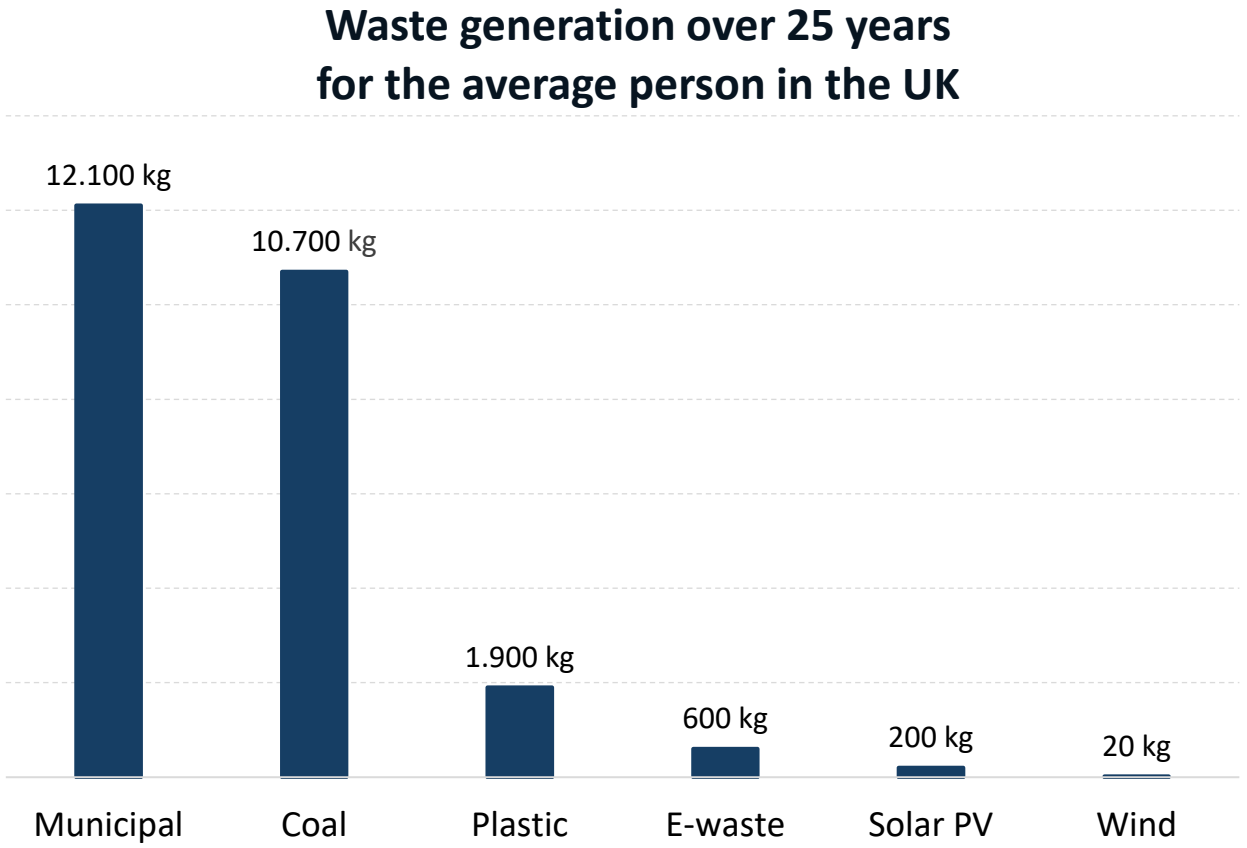
Recycling wind turbines

Viral images without a context means nothing without concrete and comparable data

Photo Credit: Benjamin Rasmussen/Getty Images



** Electricity waste assumes that all of a person's electricity came from that one source (e.g. all from coal or all from solar PV)*

Chart Source: Hannah Ritchie, "Clearing the air", 2025. Data **sources:** Calculated based on industry figures; Center for Sustainable Systems, UMichigan; David Osmond; CleanTechnica; EIA; World Bank; OECD; Global E-waste Monitor

Effective Repowering and Recycling practices [1]

Case study

- PPC Renewables removed 101 WTGs and replaced them by 23 (in 9 Greek islands)
- Less turbines, same installed capacity
- Old wind turbines materials (concrete, metals, blades, etc.) received and recycled or managed by specialized companies accredited and licensed for this purpose
- Foundations dismantling
- Landscape restoration

Source: PPC Renewables

Effective Repowering and Recycling practices [2]

Reuse or Repurpose

Blades are being repurposed and used as office desks, benches.


Source: Urban Blades


Source: PPC Renewables


Source: Urban Blades

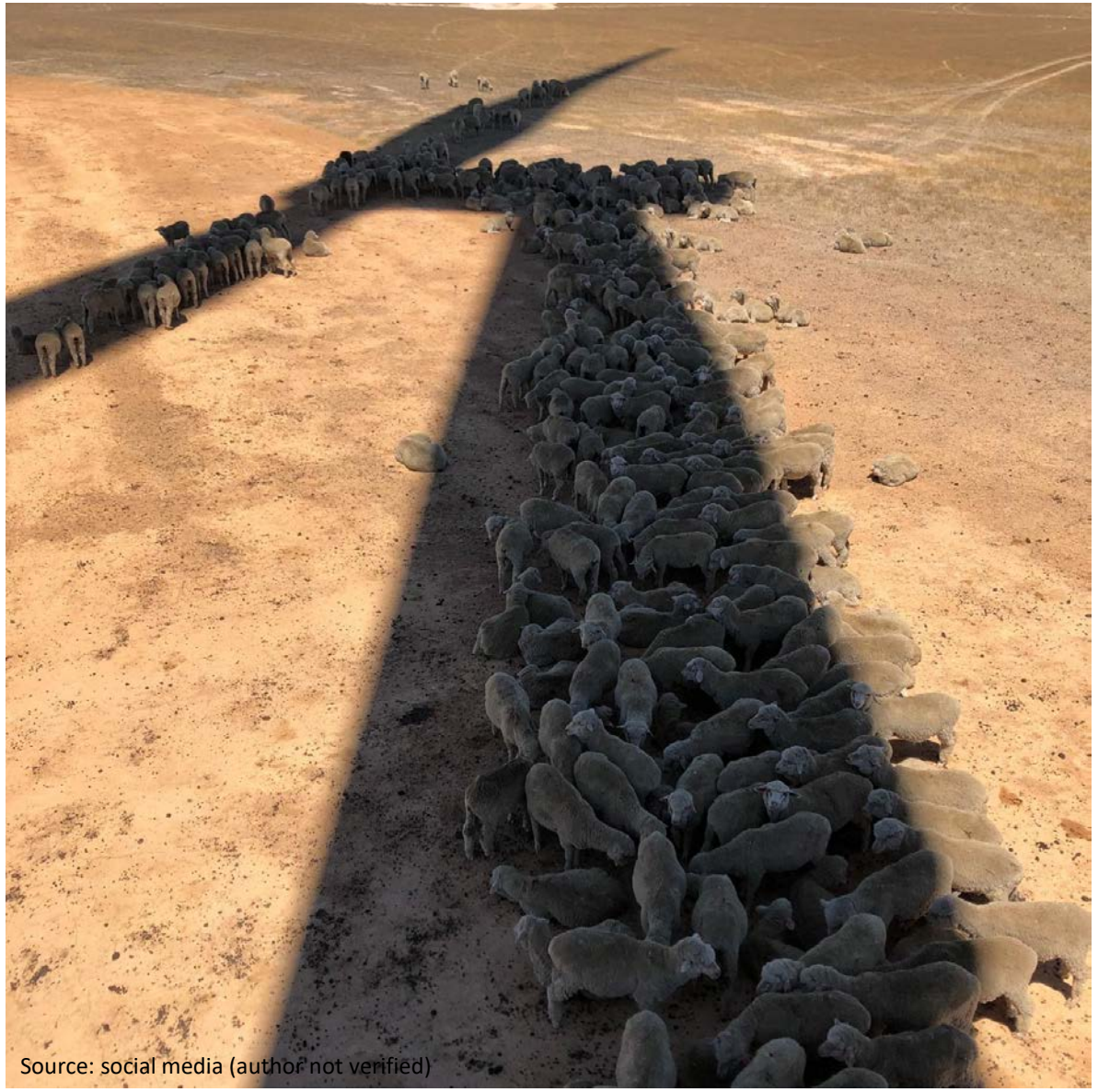
Wind energy and Cattle Breeding

Construction

- Wetting of roads to prevent dust-related nuisance
- Ramps to allow the movement of animals
- Provide livestock feed, water, etc.

Operation (positive impacts)

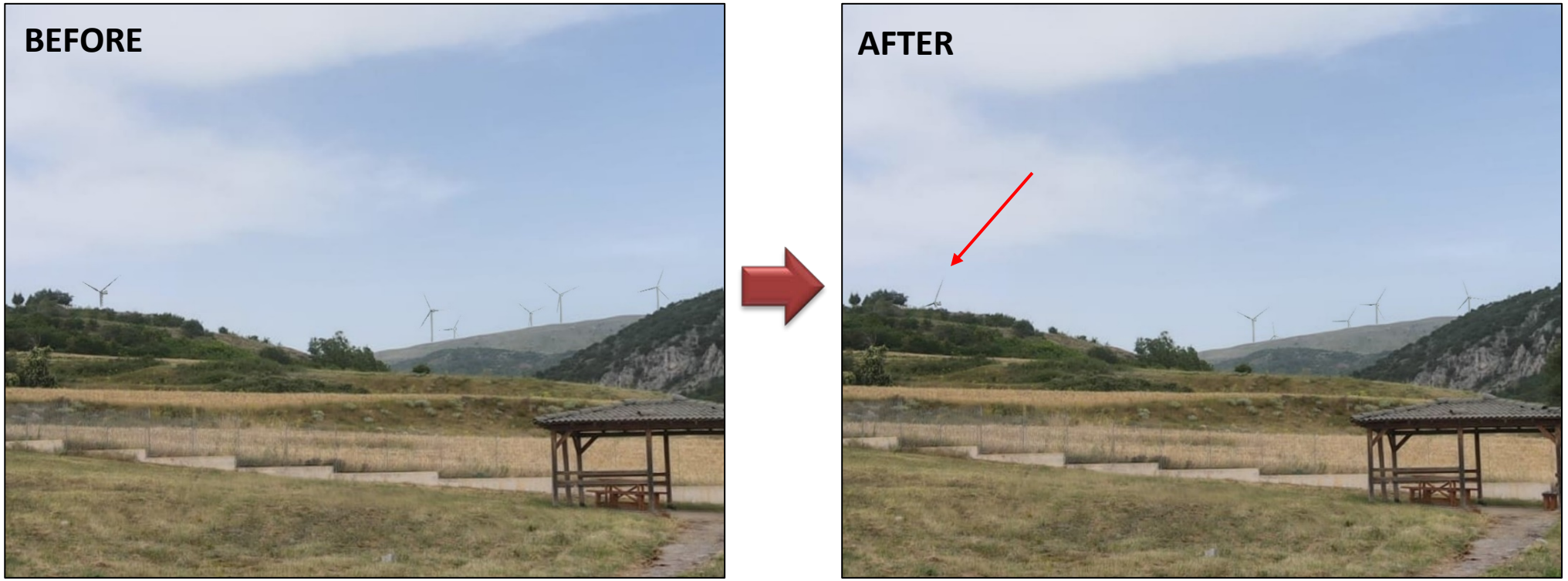
- Facilitating the movement of cattle breeders
- Forest roads maintenance
- Permanent water basins



Source: social media (author not verified)

Visual impact

Minimization of the visual impact by relocating wind turbines, or by reducing tower height

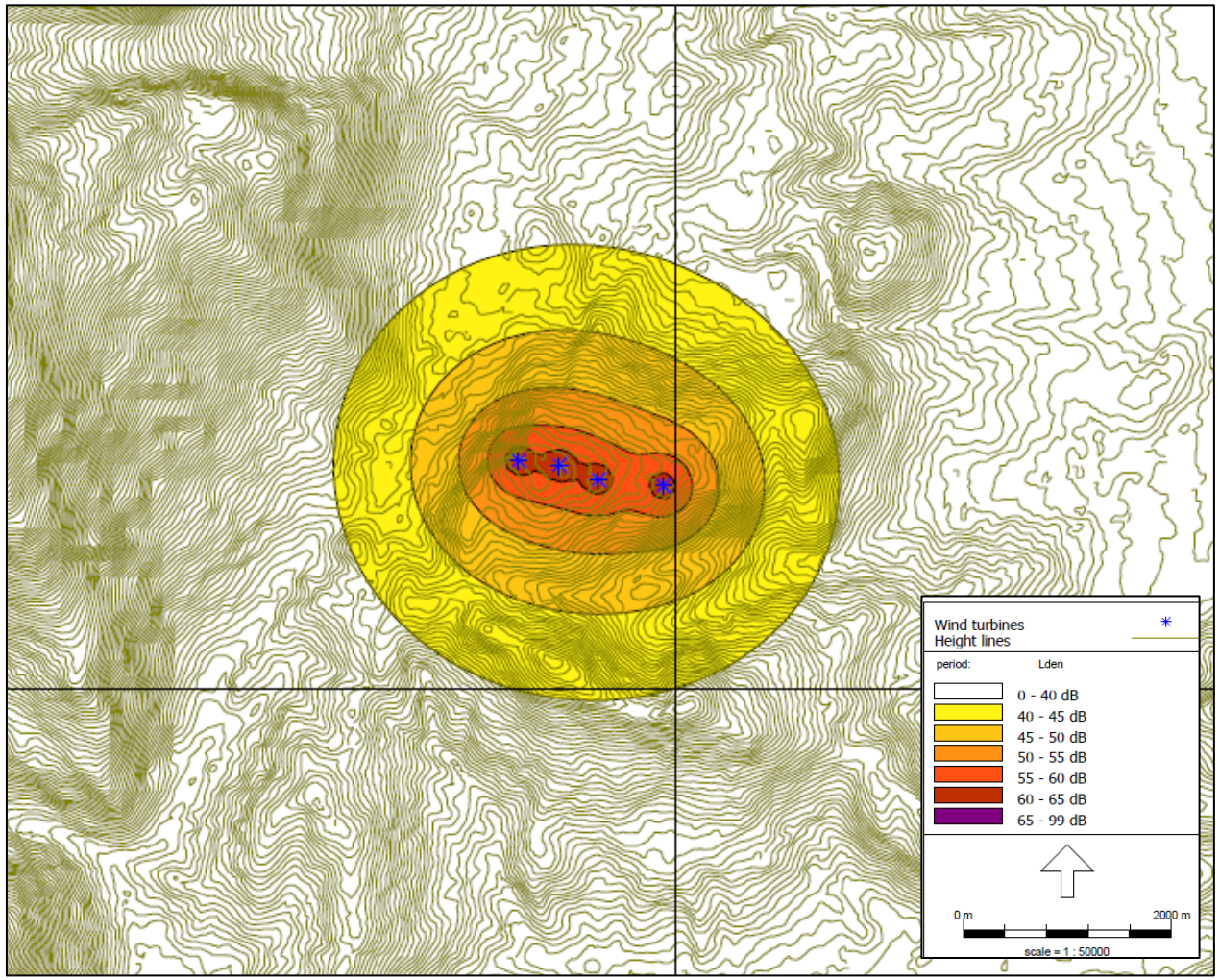


Acoustic environment

Presidential Decree 1180/1981 (GG 293/A/1981)

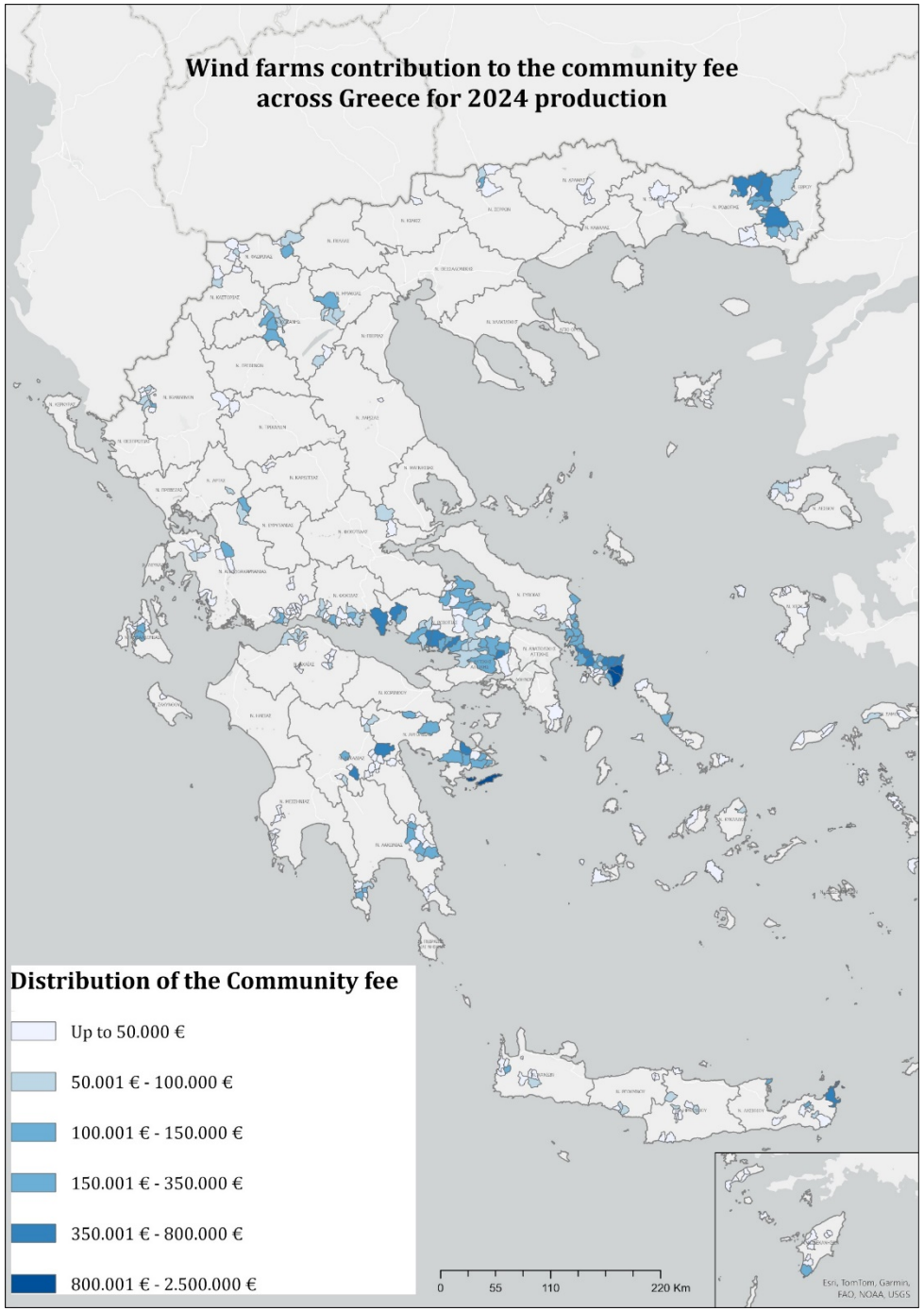
The maximum permissible noise level in dB(A) from all types of fixed mechanical installations in residential areas is set at **50 dB**, regardless of the time of day or night.

Activity/Source	Noise Level dB(A)
Night in a rural area	20 - 40
Quiet room	35
Wind Power Station	**35 – 45** (350m from the source)
Office workplace	60
Aircraft take-off	105 (250 m from the source)



Local and National benefits

- 3% community fee
- Local employment opportunities (temporary & permanent)
- Contribution to local economic activity
- Support for local development projects
- Energy independence
- Reduction of CO_2 emissions



Community fee of 3% provided by the law

355,7 mio €
total fee given to the regions
hosting RES projects, for the years 2010-2024

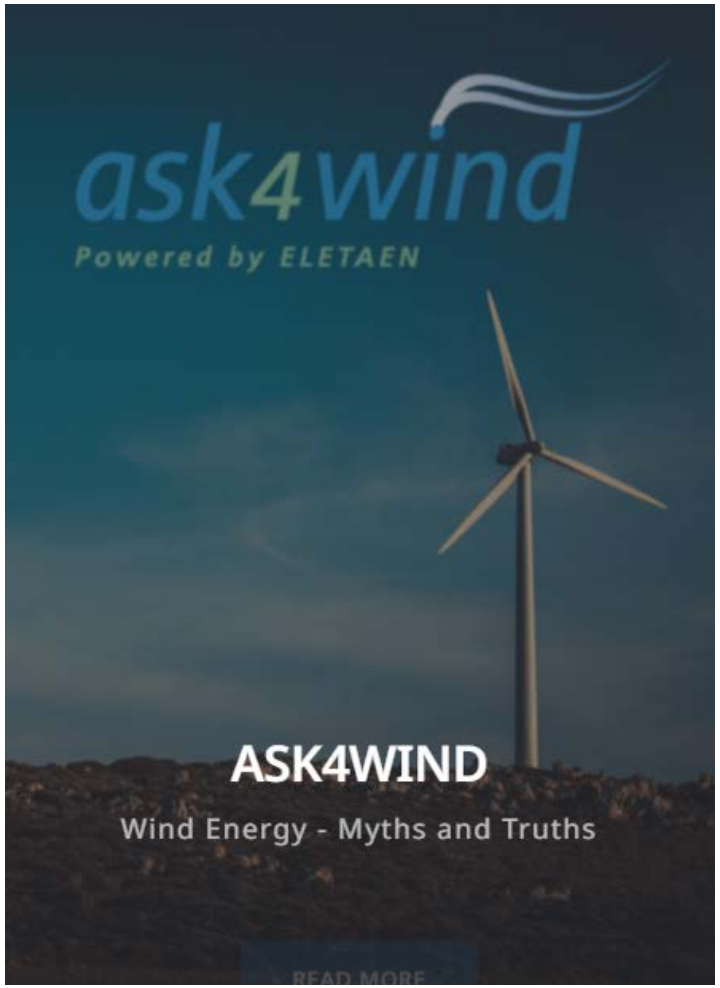
208 mio €
to the **municipalities** for infrastructure, cultural & environmental projects

126,5 mio €
to lower the **electricity bills** of the households

21,2 mio €
(period 2010-2020)
to the **Green Fund**

Sources:
1. Law N.4964/2022, article 87 (GG 150 A)
2. Annual Decisions of the Ministry of Environment and Energy for the distribution of the fee
3. HWEA Press release on the distributed fees for the 2024 production https://eletaen.gr/d-t-oikonomiki-syneisfora-apo-eidiko-telos-ape-2024/

Need to fight the fake news and myths against wind energy



Provide concrete answers to the most spread fake news against wind energy

Topics touched:

- Technology and cost of energy
- Society and Development
- Climate change
- Humans and environment

https://ask4wind.gr/

Image credit: NASA/Reid Wiseman (Artemis II, 2026)