

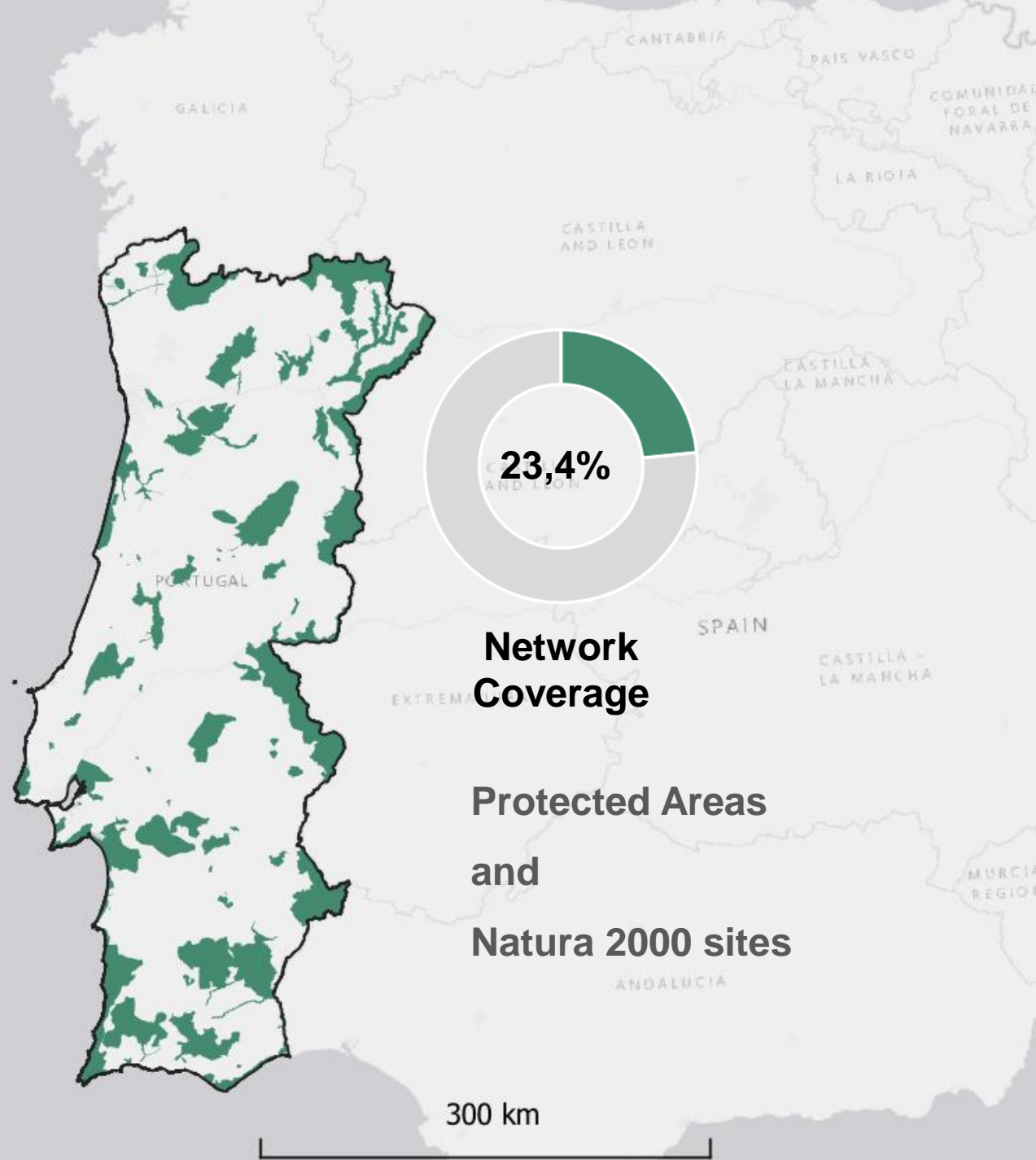


# Wind Energy and Land Cover: The Case of Portugal in a Mediterranean and European Context

Paulo Cardoso e Miguel Mascarenhas  
Verde.tec 2025  
22/02/2025

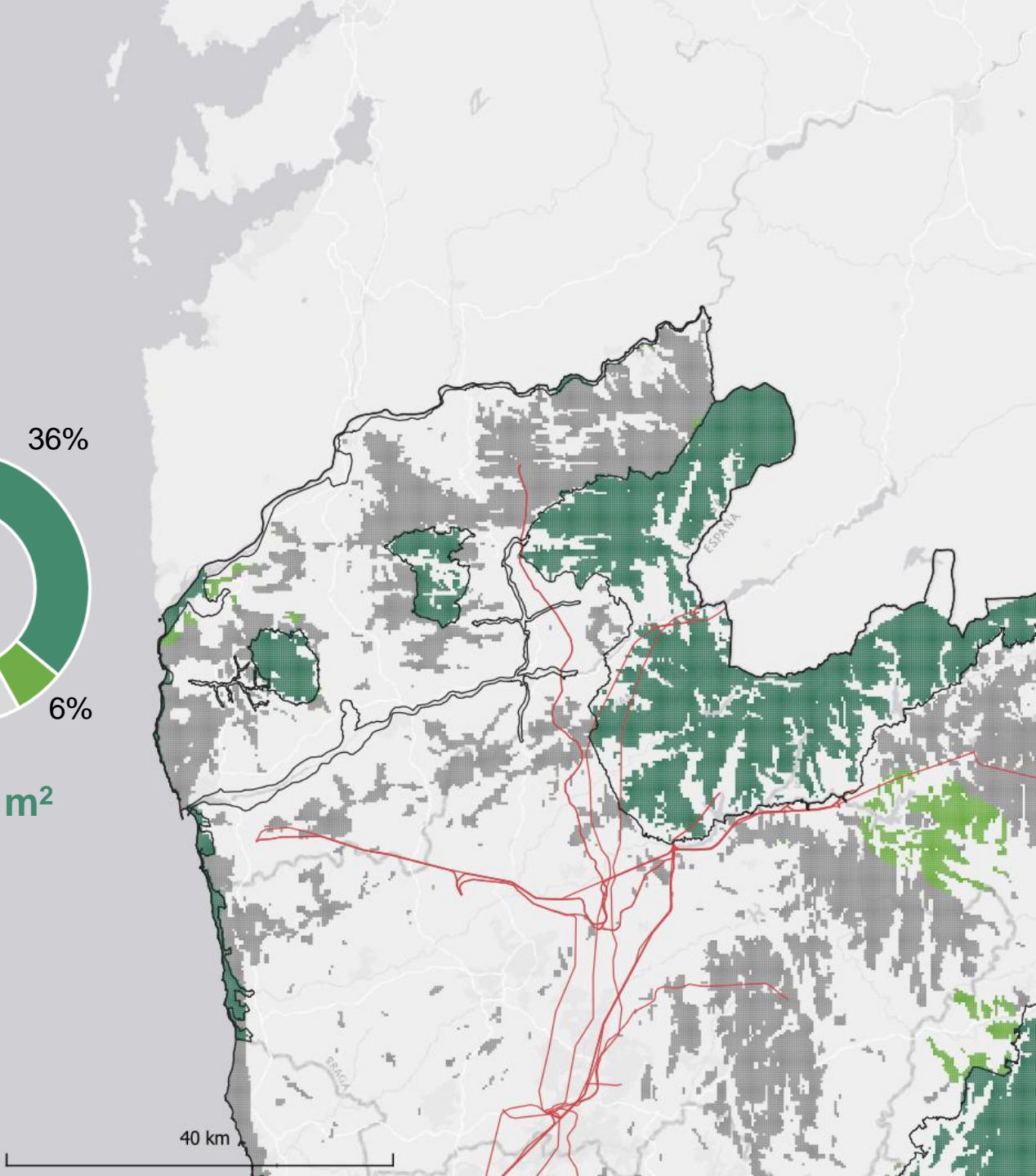
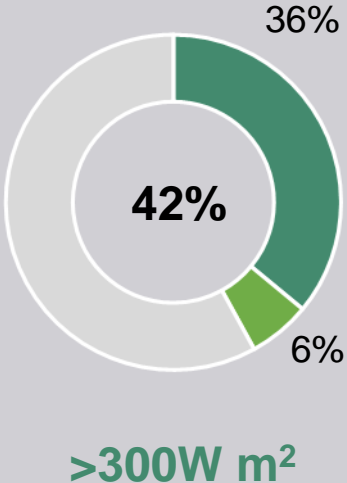


# Context

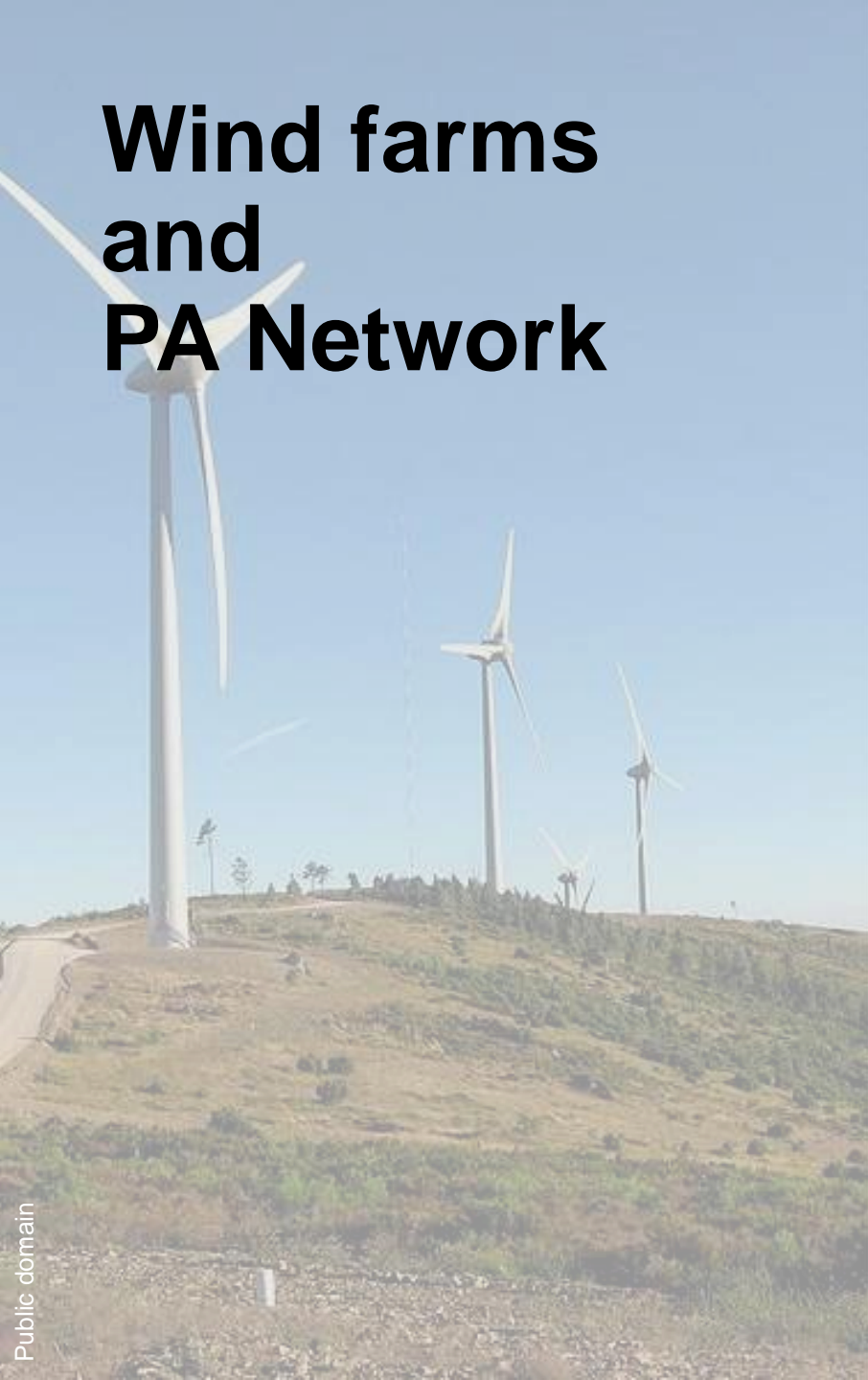


# Wind Resource

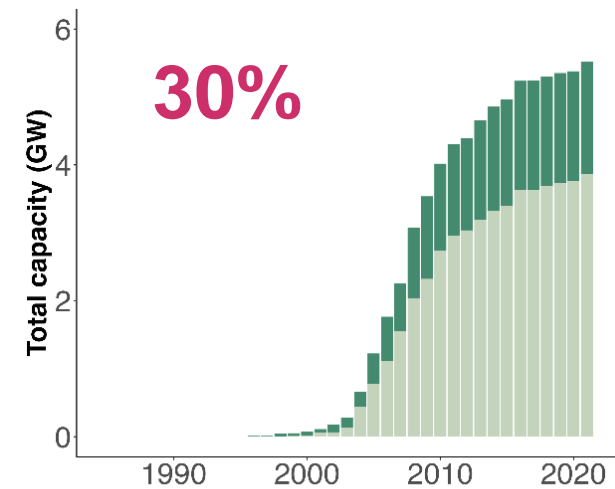
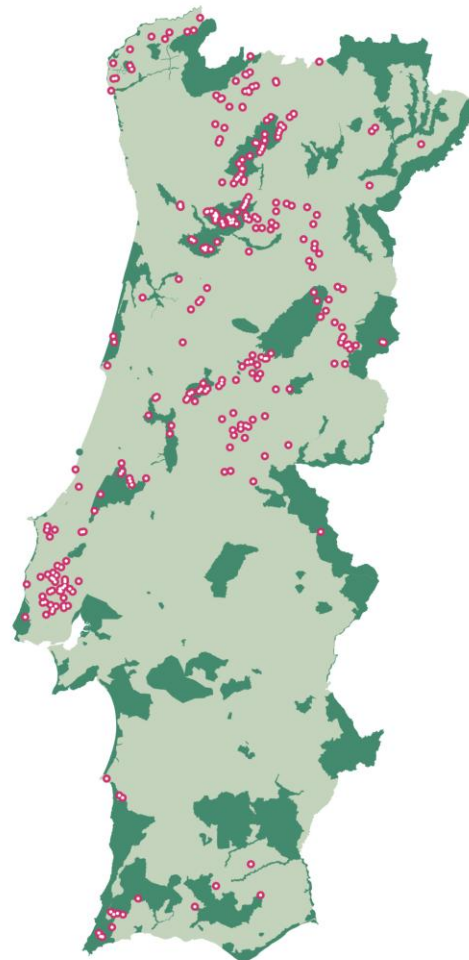
Wind Resources  
Inside PA Network & other  
environmentally sensitive areas



# Wind farms and PA Network



2021  
5,7GW  
288 windfarms  
2640 turbines



# How we are affecting our land and sensitive areas?

Data from centralized source of all EIA processes in Portugal



Sistema de Informação sobre Avaliação de Impacte Ambiental

[Menu](#) : AIA todos os projetos

Nº AIA	Designação do projeto	Proponente	Licenciador	Localização	Autoridade AIA	Data da decisão	Sentido da decisão
3810	<a href="#">Central Solar Fotovoltaica (CSF) do Brejo</a>	CENTRAL FOTOVOLTAICA DE BREJO, S.A.	DGEG - Direcção-Geral de Energia e Geologia	OURIQUE	Agência Portuguesa do Ambiente, I.P.	.	.
3809	<a href="#">Concessão Mineira C-175 "Cartaria"</a>	Sabril - Sociedade Areias e Britas, Lda.	DGEG - Direcção-Geral de Energia e Geologia	POMBAL	Agência Portuguesa do Ambiente, I.P.	.	.

[https://siaia.apambiente.pt/AIA\\_Todos.aspx](https://siaia.apambiente.pt/AIA_Todos.aspx)

# Dataset

- Retrieved data from EIA
- Period 2010-2025
- 1.1 GW
- 19% of installed Capacity in 2024

## Metadata

Process Code	Year	Process Link	N of Turbines	Installed Capacity	Technical Report Link	Project Name	Nacelle Height	Rotor Diameter	Maximum Height
3747	2025	<a href="https://siaia.apambiente.pt/AIA1.aspx?ID=3747">https://siaia.apambiente.pt/AIA1.aspx?ID=3747</a>	25	165	<a href="https://siaia.apambiente.pt/AIADOC/AIA3747/volu-me1rtv120251816331.pdf">https://siaia.apambiente.pt/AIADOC/AIA3747/volu-me1rtv120251816331.pdf</a>	Projeto de Hibridização da Central Fotovoltaica de Alcoutim (Parque Eólico SOLARA4)	115	170	200

## Afected areas from EIA/EInca

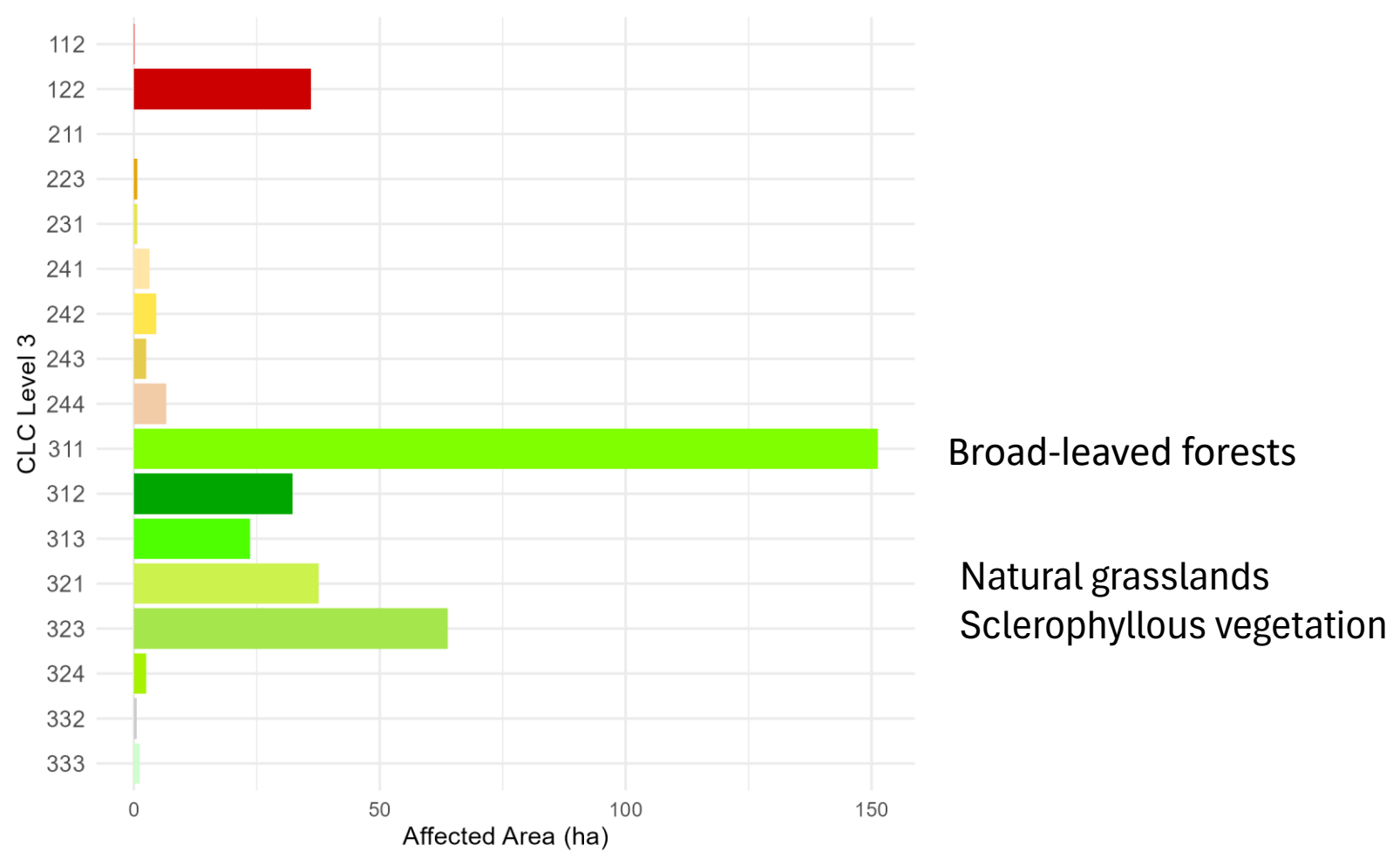
AIA Proc	Land Cover	CLC Level3	Turbine Platforms and Foundations	Access Roads and Slopes	Trenches for Electrical Cables	Switching Station	Substation	Total Affected Area
3747	Vegetação natural e seminatural	Natural grasslands	15.42	16.27	1.97	0.14	0	33.8
3747	Matos (esteval)	Sclerophyllous vegetation	6.79	6.29	0.37	0	0	13.45
3747	Matos (esteval) com quercíneas dispersas	Sclerophyllous vegetation	7.32	8.3	1.46	0.14	0	17.22



# Land Transformation

## Our sample

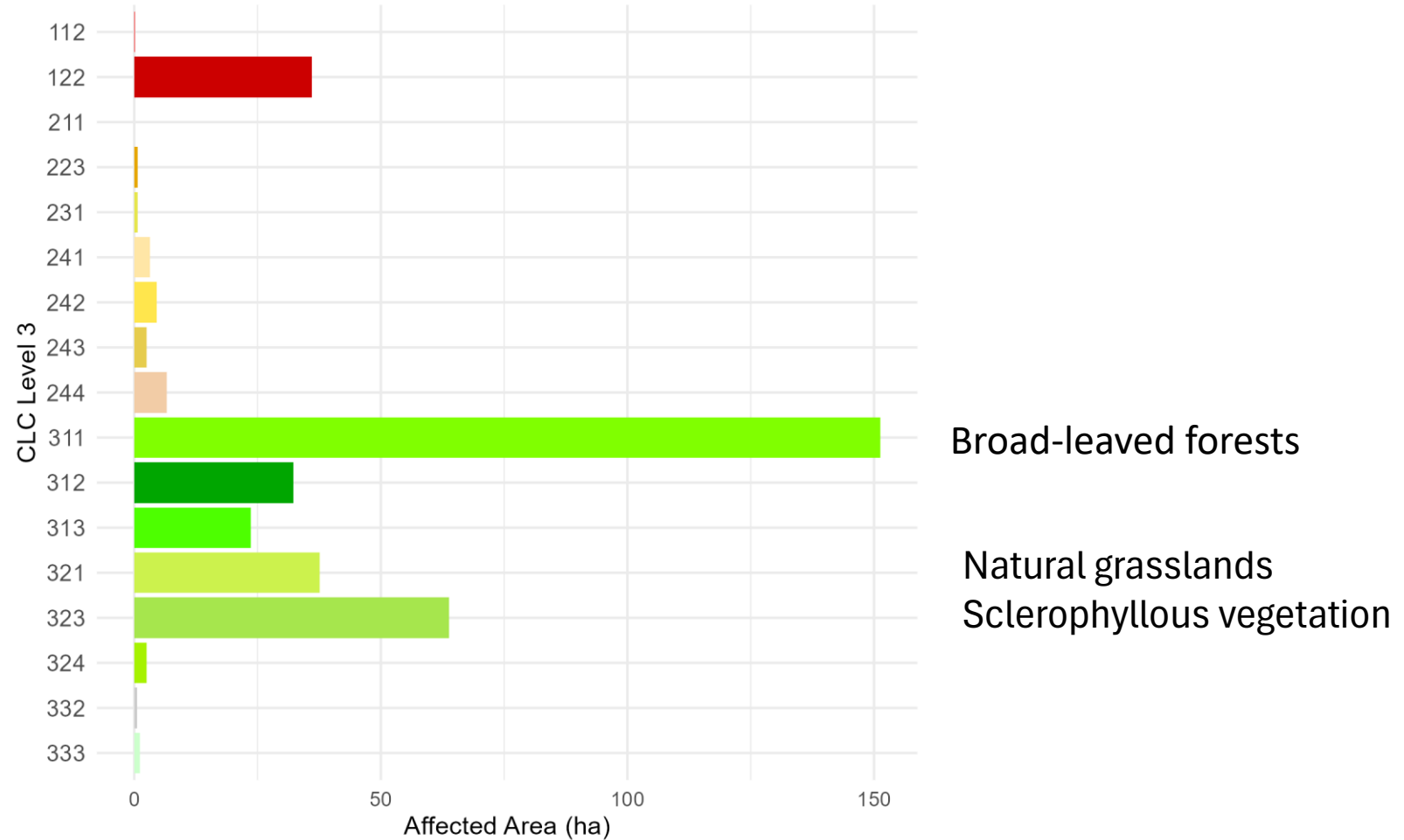
- 1.1 GW
- All permanent infrastructures
- 19% of installed capacity in 2024



# Land Transformation

## Our sample

- 1.1 GW
- All permanent infrastructures
- 19% of installed capacity in 2024



## Comparisons

Study	Geography	Area/MW
Diffendorfer J., Compton R., 2014	EUA (1,9 GW)	0.93
Diamianidis Chr. et al., 2022	North Greece (695 MW)	0.26
Kati V. et al., 2023	Greece (1.2 GW)	0.78
<b>This study</b>	<b>Portugal (1.1 GW)</b>	<b>0.36</b>





# European context

- Database of Wind turbines
  - Natura2000 sites
  - CORINE Land Cover
  - Human Footprint
- 
- Portugal, Spain, Greece, France, Belgium, Germany and Denmark
- 
- 69 900 Wind turbines

## scientific data

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[nature](#) > [scientific data](#) > [data descriptors](#) > article

Data Descriptor | [Open access](#) | Published: 29 April 2020

### Harmonised global datasets of wind and solar farm locations and power

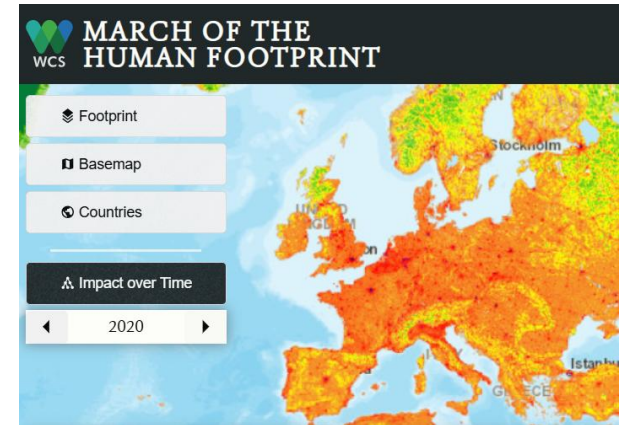
[Sebastian Dunnett](#) , [Alessandro Sorichetta](#), [Gail Taylor](#) & [Felix Eigenbrod](#)

[Scientific Data](#) 7, Article number: 130 (2020) | [Cite this article](#)

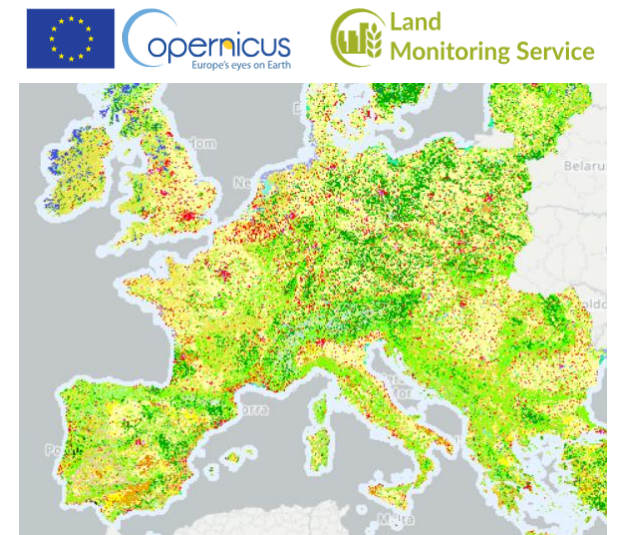
<https://www.nature.com/articles/s41597-020-0469-8>



<https://natura2000.eea.europa.eu/>



<https://wchumanfootprint.org/map/>

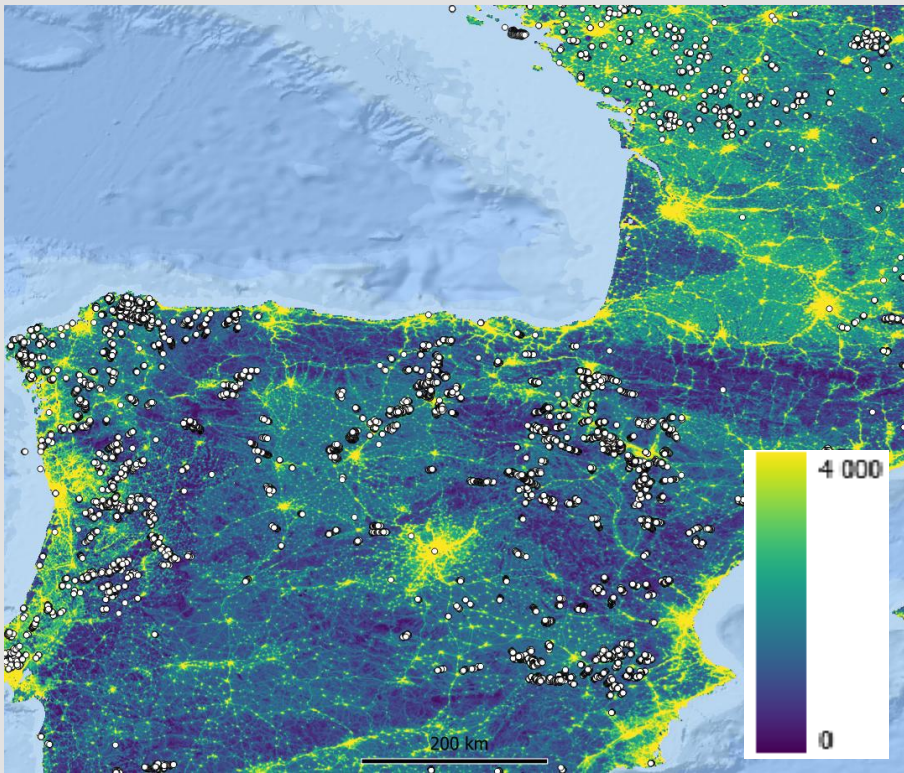


<https://land.copernicus.eu/en/products/corine-land-cover/clc2018>



# Human Footprint Index

Weighted distance algorithm to main drivers of human impact, 2000– 2019

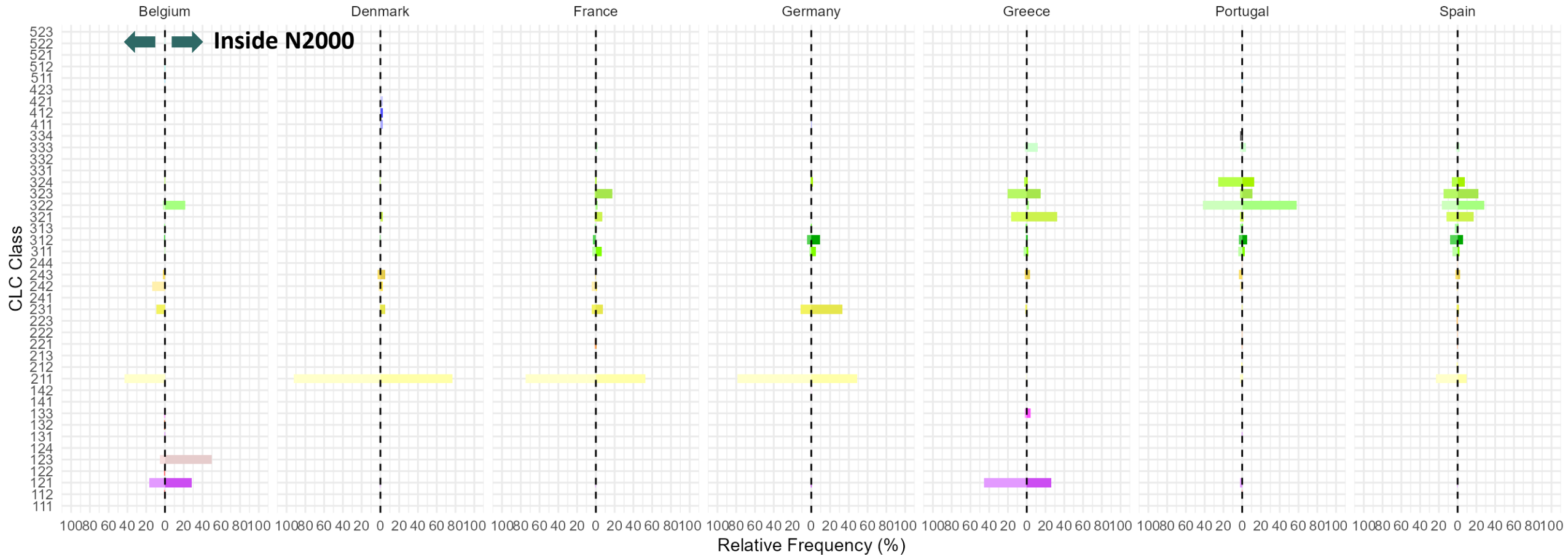


Impact driver	First generation.	Second generation.	Global dataset	Native time period; frequency	Native resolution	Human impact weighting <sup>a</sup>
Population density	√	√	WorldPop <sup>29</sup> Residential Population	2000 – present; annual	100 m	$3.333 * \log(\text{persons} / \text{km}^2 + 1)$ ; if density > 1000 persons / km <sup>2</sup> → 10
Land Cover	√	√	ESA CCI Land Cover Dataset <sup>30</sup>	1992 – present; annual	300 m	Depends on land cover class and population density; 33 classes <sup>a</sup>
Infrastructure						
... Structures	√	√	Global Human Settlement Layer <sup>28</sup>	2000 – 2014; static	30 m	10
		√	Open Street Map <sup>31</sup>	2012 – present; weekly	Vector	Depends on type; 192 types <sup>a</sup>
... Roads	√	√	gRoads <sup>28</sup>	1980 – 2010; static	Vector	8
		√	Open Street Map <sup>31</sup>	2012 – present; weekly	Vector	Depends on type; 29 types <sup>a</sup>
... Railways	√	√	Vector Map 0 <sup>27</sup>	c. 1990 – 2000; static	Vector	Depends on status; 5 classes <sup>a</sup>
		√	Open Street Map <sup>31</sup>	2012 – present; weekly	Vector	Depends on type; 14 types <sup>a</sup>
Accessibility						
... via Populated Coasts	√	√	ESA CCI Water Bodies Map <sup>51</sup>	2000; static	150 m	$e^{-(\text{distance} * -0.0003)} * 4^b$
... via Navigable Waters	√	√	Global Surface Waters <sup>51</sup>	1984 – present; annual	30 m	$e^{-(\text{distance} * -0.0003)} * 4^b$
... via Roads	√	√	gRoads <sup>28</sup>	1980 – 2010; static	Vector	$e^{-(\text{distance} * -0.0003)} * 4^c$
		√	Open Street Map <sup>31</sup>	2012 – present; weekly	Vector	$e^{-(\text{distance} * \text{constant})} * \text{weight}^c$
Power	√					
		√	Inter-calibrated stable nighttime lights series from DMSP <sup>32,38</sup>	1992 – 2019; annual	30 arc-seconds	10 equal area quantiles <sup>d</sup> → 0 - 10
		√	Inter-calibrated stable nighttime lights series from VIIRS <sup>33,38</sup>	2014 – present; annual	15 arc-seconds	10 equal area quantiles <sup>d</sup> → 0 - 10

# Land transformation inside/outside Natura 2000 sites

Wind turbines position only  
CORINE pixel ~100m

Relative Frequency of CLC Classes Inside and Outside Natura 2000

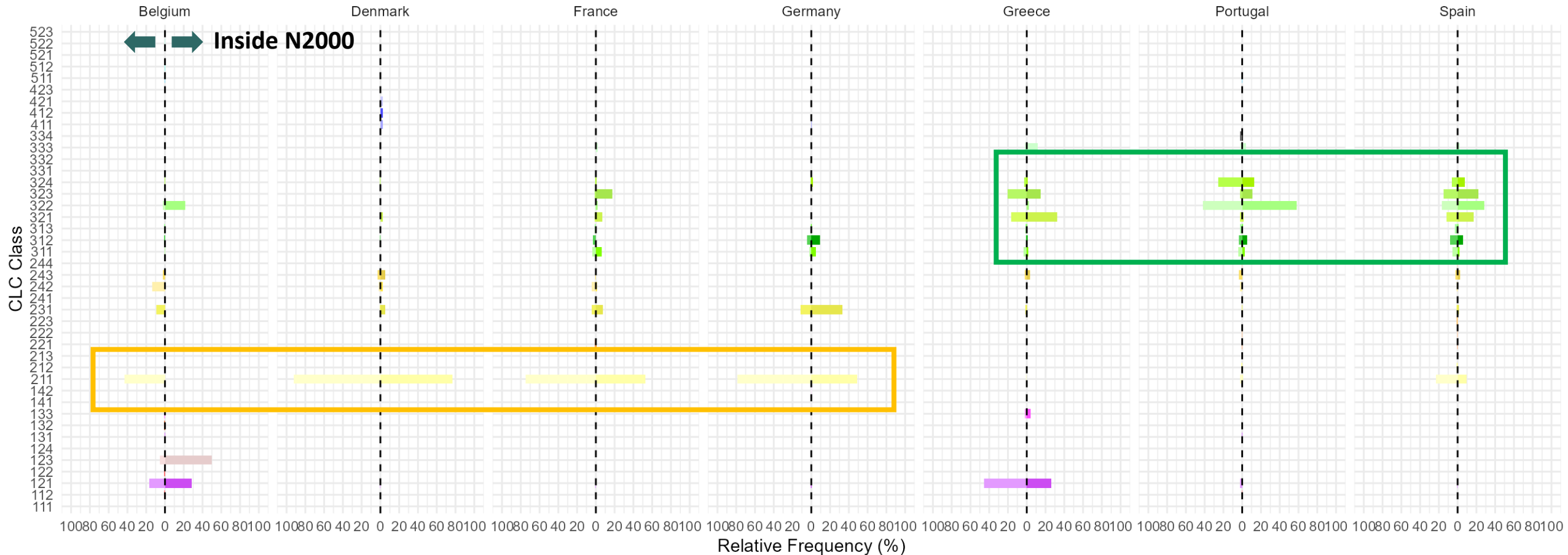


# Land transformation inside/outside Natura 2000 sites

Non-irrigated arable land  
Industrial or commercial units

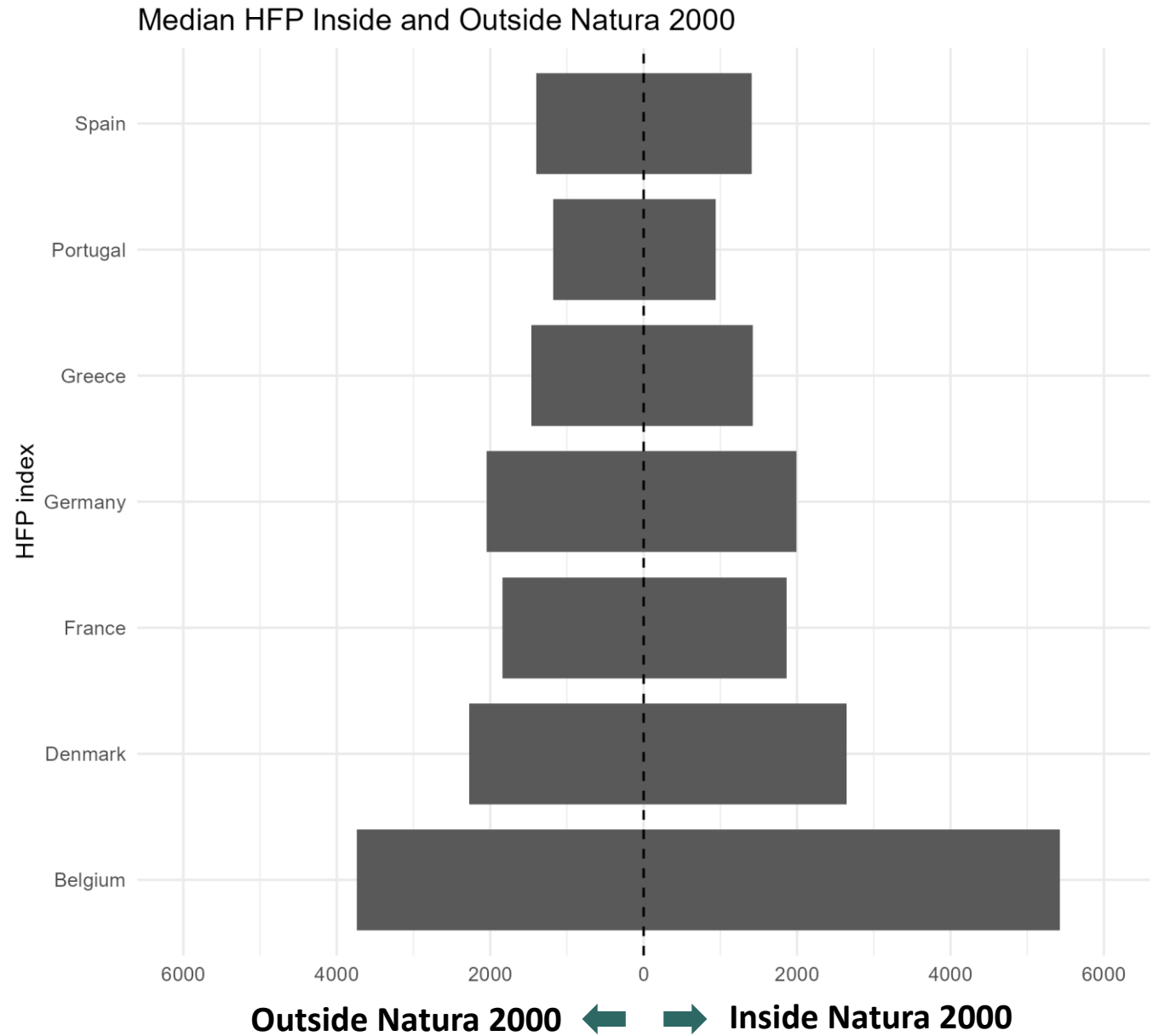
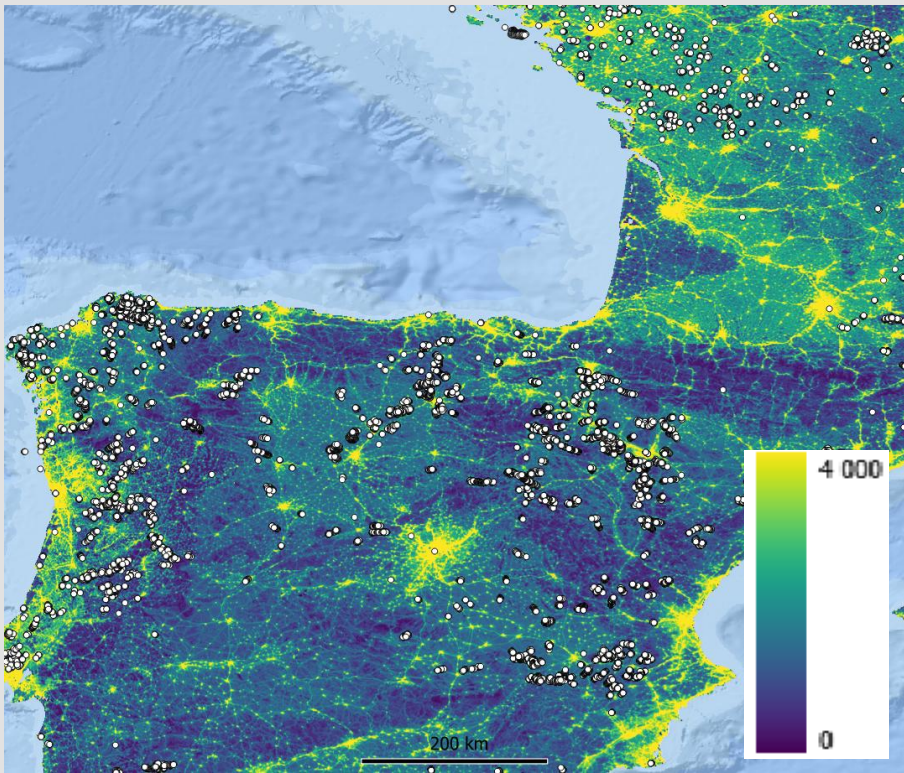
Natural grasslands  
Moors and heathland  
Sclerophyllous vegetation

Relative Frequency of CLC Classes Inside and Outside Natura 2000



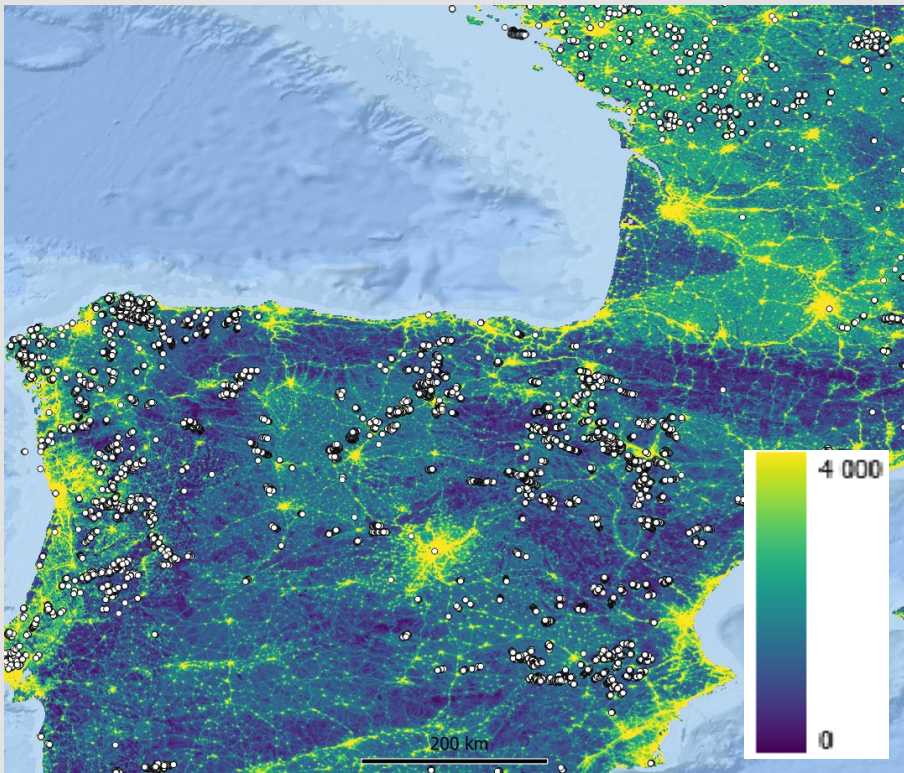
# Human Footprint Index

Wind turbines positions  
HFI pixel ~200m

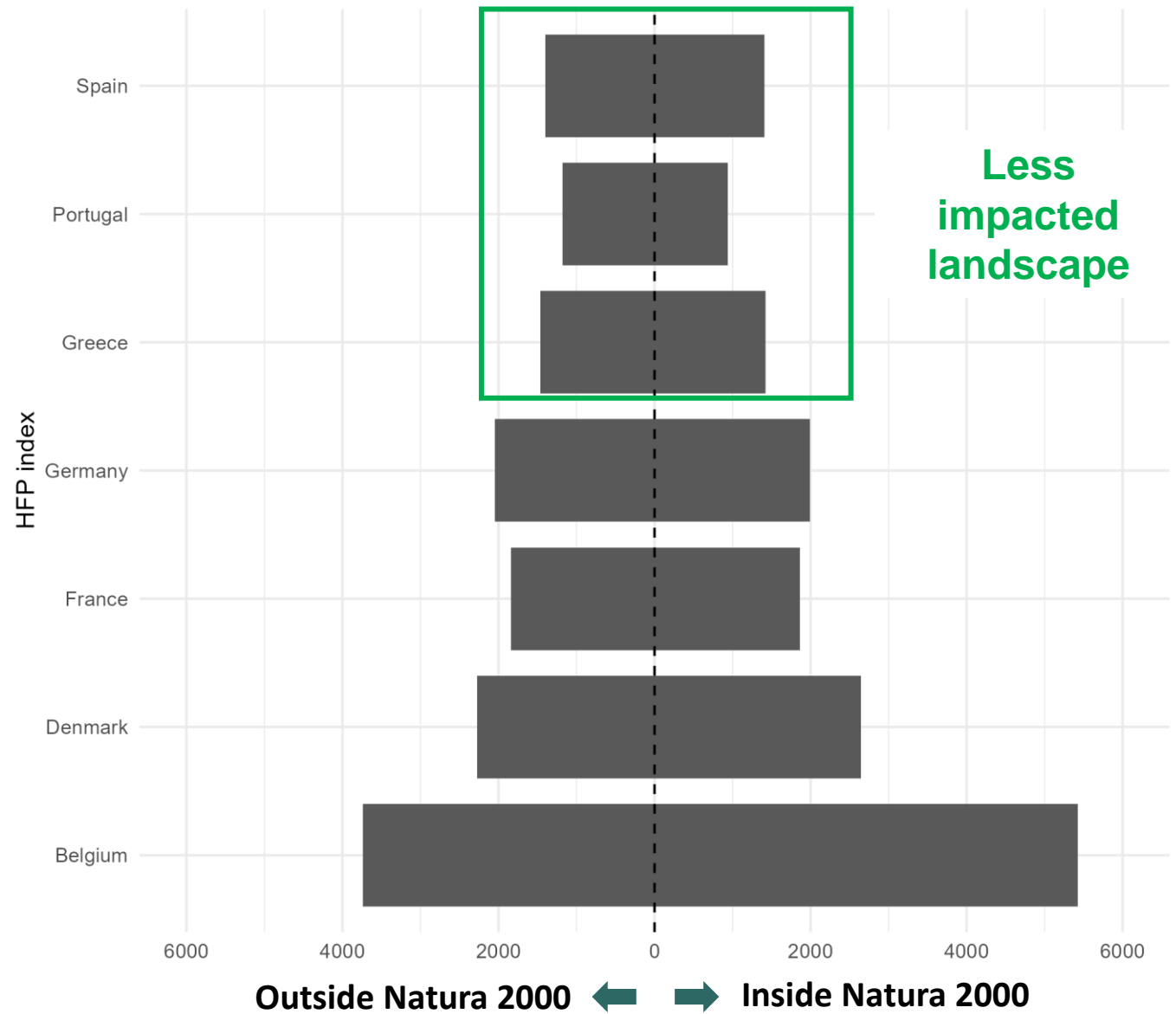


# Human Footprint Index

Wind turbines positions  
HFI pixel ~200m



Median HFP Inside and Outside Natura 2000



# Call for action

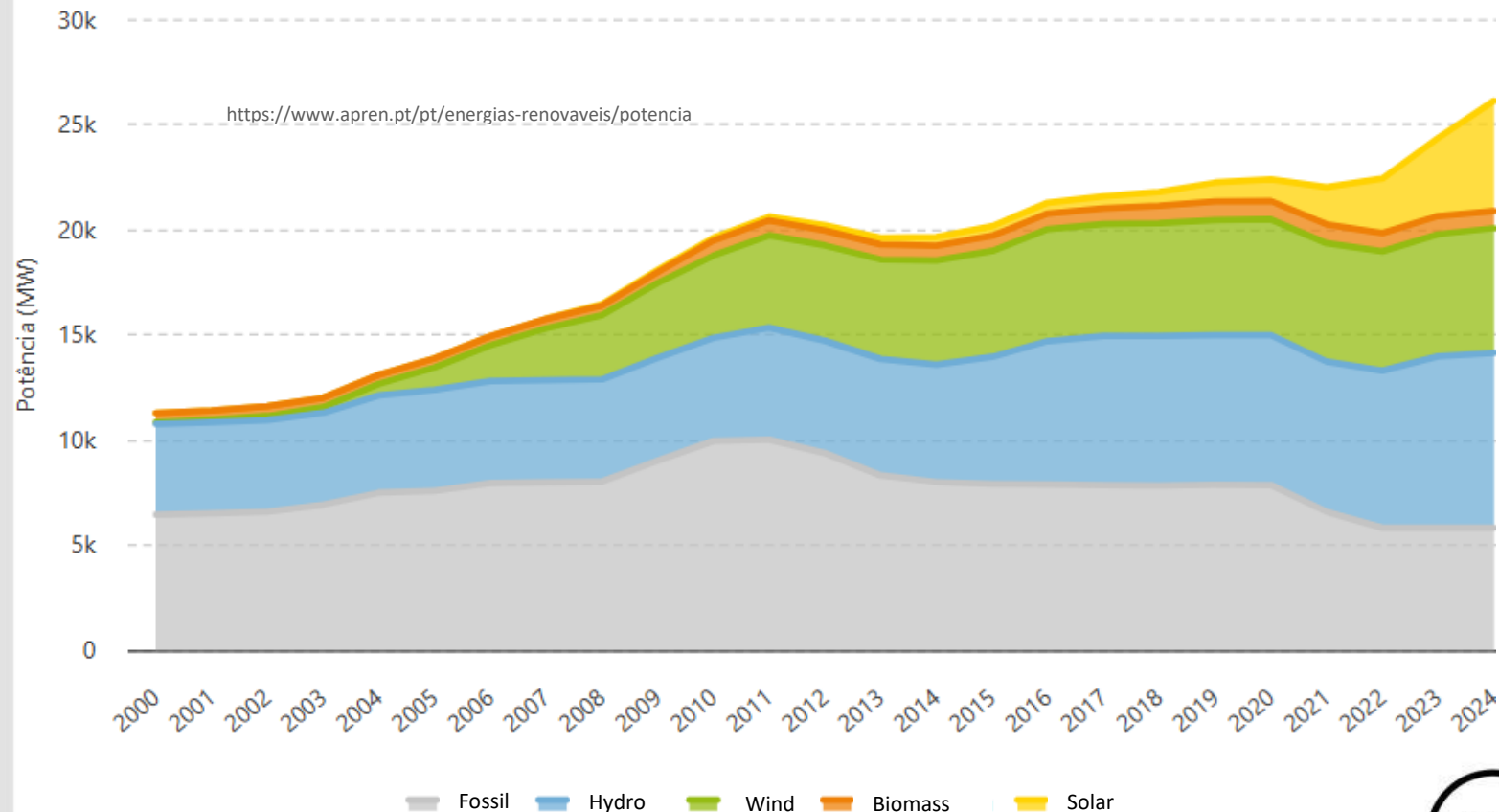
Speed up the Energetic Transition

44% expected increase in Portugal

REPOWER EU increase the EU's 2030 target for renewables from the current **40% to 45%**

2024 5,9 GW installed (wind)  
2023 35,2 % Gross Final Consump.

2030 PT NECP  
8,50 GW wind  
51% Gross Final Consump.



Resolução do Conselho de Ministros n.º 149/2024, de 30 de outubro

[https://energy.ec.europa.eu/system/files/2019-06/pt\\_swd\\_en\\_0.pdf](https://energy.ec.europa.eu/system/files/2019-06/pt_swd_en_0.pdf)

[https://energy.ec.europa.eu/system/files/2019-06/necp\\_factsheet\\_pt\\_final\\_0.pdf](https://energy.ec.europa.eu/system/files/2019-06/necp_factsheet_pt_final_0.pdf)



# Context-specific conflict

NIMBY-explanation ('Not In My Back Yard') and micro-sociology

Conflicts with Fragmentation and Nature Conservation



Utilities Policy  
Volume 41, August 2016, Pages 214-227



## Against the wind: Local opposition to the German *Energiewende*

Fritz Reusswig <sup>a</sup> , Florian Braun <sup>b</sup>, Ines Heger <sup>a</sup>, Thomas Ludwig <sup>c</sup>,  
Eva Eichenauer <sup>a</sup>, Wiebke Lass <sup>a</sup>



Journal of Environmental  
Management  
Volume 348, 15 December 2023, 119340



Research article

## The overlooked threat of land take from wind energy infrastructures: Quantification, drivers and policy gaps

V. Kati <sup>a</sup> , C. Kassara <sup>a</sup> , P. Panagos <sup>b</sup>, L. Tampouratzi <sup>a</sup>, D. Gotsis <sup>a</sup>,  
O. Tzortzakaki <sup>a</sup>, M. Petridou <sup>a</sup>, M. Psaralexi <sup>a</sup>, L. Sidiropoulos <sup>a</sup>, D. Vasilakis <sup>a</sup>,  
S. Zakkak <sup>a</sup> <sup>c</sup>, A. Galani <sup>a</sup>, N. Mpoukas <sup>a</sup>



Article

## Community Acceptance of Wind Energy Developments: Experience from Wind Energy Scarce Regions in Europe

Merethe Dotterud Leiren <sup>1,\*</sup>, Stine Aakre <sup>1</sup>, Kristin Linnerud <sup>1</sup>, Tom Erik Julsrud <sup>1</sup> ,  
Maria-Rosaria Di Nucci <sup>2</sup> and Michael Krug <sup>2</sup>

<sup>1</sup> CICERO Center for International Climate Research, 0349 Oslo, Norway; stine.aakre@cicero.oslo.no (S.A.); kristin.linnerud@cicero.oslo.no (K.L.); tom.julsrud@cicero.oslo.no (T.E.J.)

<sup>2</sup> Environmental Policy Research Centre, Freie Universität Berlin, D-14195 Berlin, Germany; dinucci@zedat.fu-berlin.de (M.-R.D.N.); mikru@zedat.fu-berlin.de (M.K.)

\* Correspondence: merethe.leiren@cicero.oslo.no

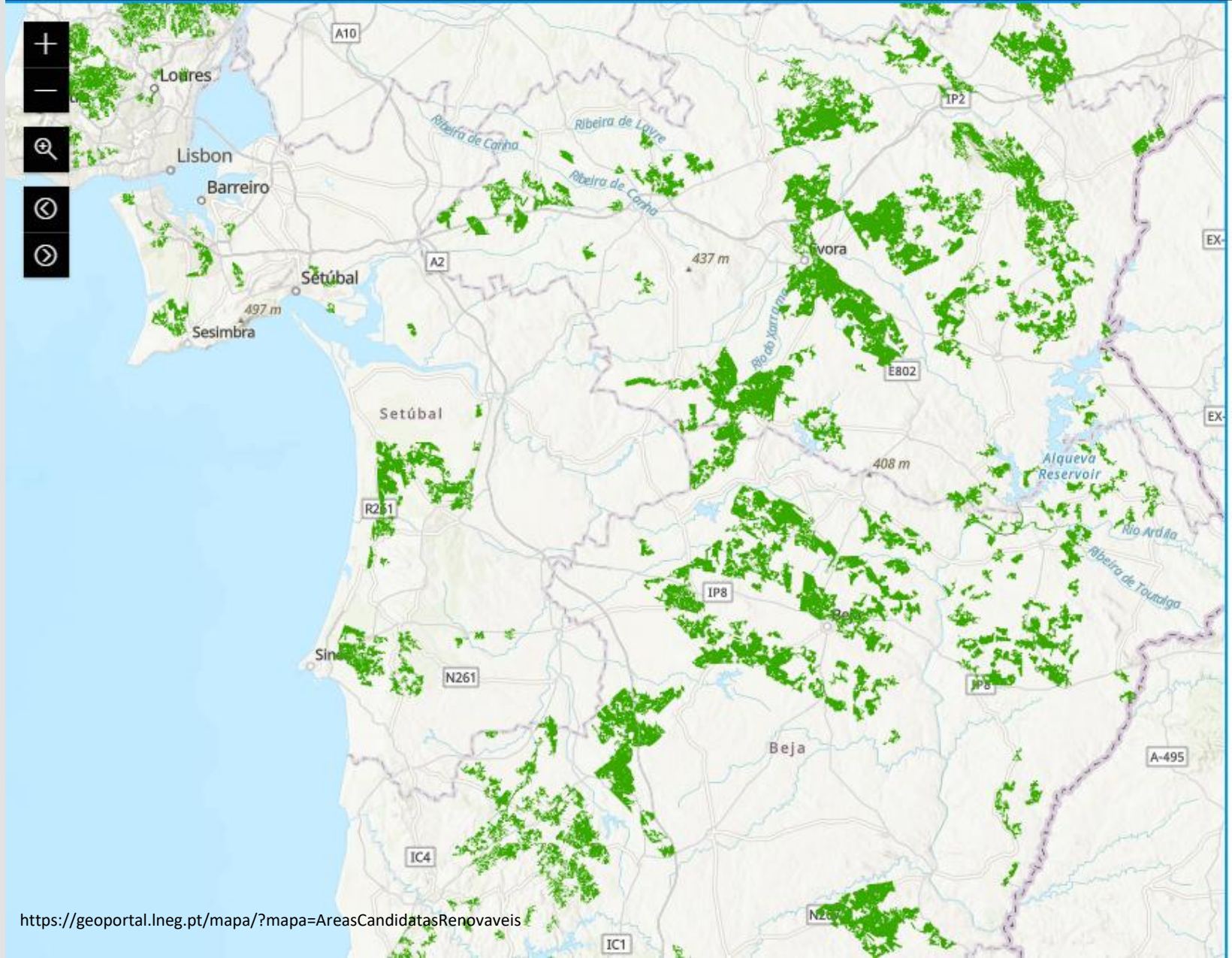




# National initiative

## Map of less sensitive areas to wind and solar

~3% of Continental Territory  
2.65 km<sup>2</sup>



[https://www.ineg.pt/wp-content/uploads/2023/07/2aVersaoMapaAreasMenosSensiveis\\_Jul2023.pdf](https://www.ineg.pt/wp-content/uploads/2023/07/2aVersaoMapaAreasMenosSensiveis_Jul2023.pdf)

<https://geoportal.ineg.pt/mapa/?mapa=AreasCandidatasRenovaveis>

# Key Takeaways

- **Promote multisector dialog based on evidence**
- **Explain the development context**
- **Do these before developing**
  
- **Promote transparent EIA**
- **Apply the mitigation hierarchy**
- **Mindset on positive impacts**



**Thank you !**