Construction of wind turbines linked to reductions in physical health-related quality of life: Empirical evidence using linked administrative and panel data from Germany (2002-2020)

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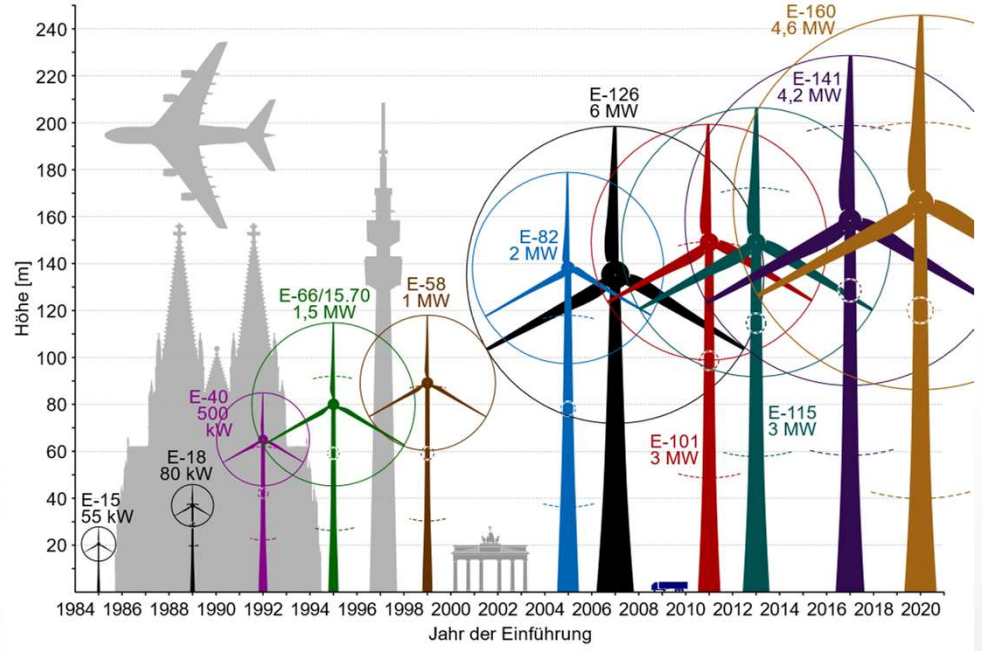
The issue – the rollout of windturbines

- First documented windturbine (WT) for energy production constructed 1883 by Josef Friedländer at Prater in Vienna
- In Germany, take-off since the Electricity Feed-in Act (1991) and the Renewable Energy Act (2000)
- Pushed for geostrategic reasons and climate protection
- Nowadays, around 30k WT

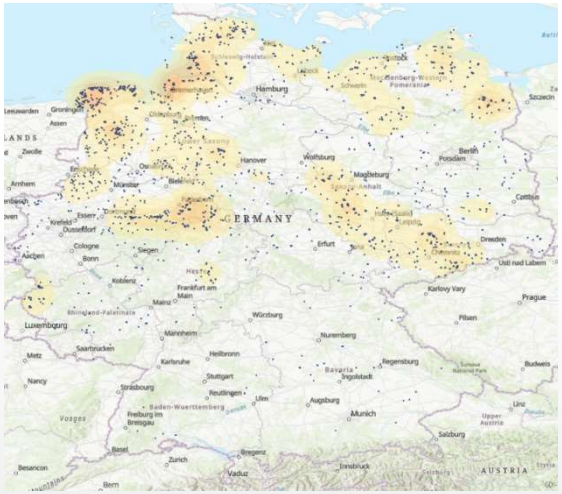


Gundi Knies

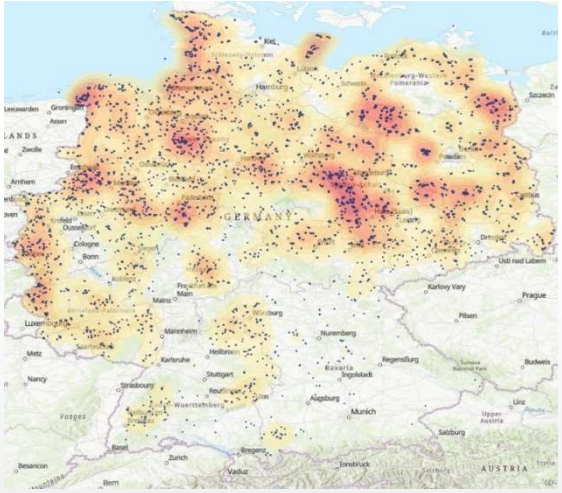
WT in Germany 1983-2020 (kernel density estimation)

- rapid increase since 2000, esp. in the North and North-East
- further push since 2010, esp. in the South East

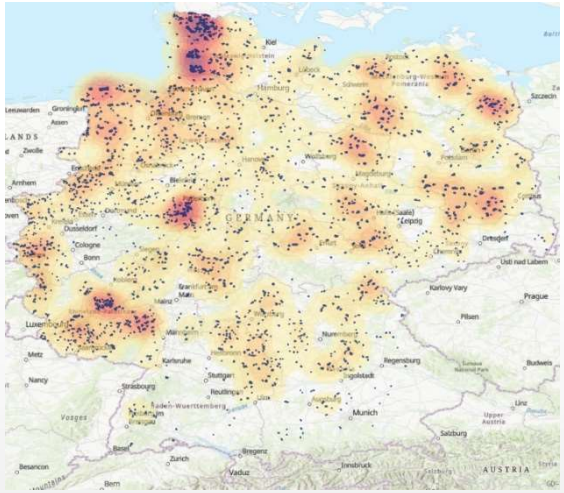
1983 to end of 1999 (new: 3,345)



2000 to end of 2009 (new: 12,931)



2010 to end of 2020 (new: 11,701)



Source: Marktstammdatenregister (MaSTR, Date: 31.03.2023) with own corrections.

The issue – critiques of wind energy

Construction of onshore WT predominantly in rural areas; often not well received in the population (e.g. Batel und Devine-Wright 2015; Eichenauer 2018)

Conflicts around:

- Protection of species and biotopes
  (esp. birds and bats)
- Landscape attractiveness (& property values)
- health impacts (esp. through noise incl. infrasound)

The discourse about the influence of wind turbines on health via infrasound (1)

- Few empirical studies, esp. studies using causal research designs.
- Federal Environment Agency (Umweltbundesamt 2021) presently works on the assumption that infrasound from WT does not cause health issues.

WT critics

Various symptoms due to wind turbines

WT supporters, medics and engineers

Nocebo!

The discourse about the influence of wind turbines on health via infrasound (2)

Symptoms

- Sleep and concentration disorders
- decreased respiratory rate
- Anxiety attacks and dizziness
- Tinnitus
- Headache
- long-term exposure: permanent alarm situation (increase in the stress hormone cortisol -> psychological instability with measurable physical reactions such as increase in blood pressure, risk of heart attack, etc.)

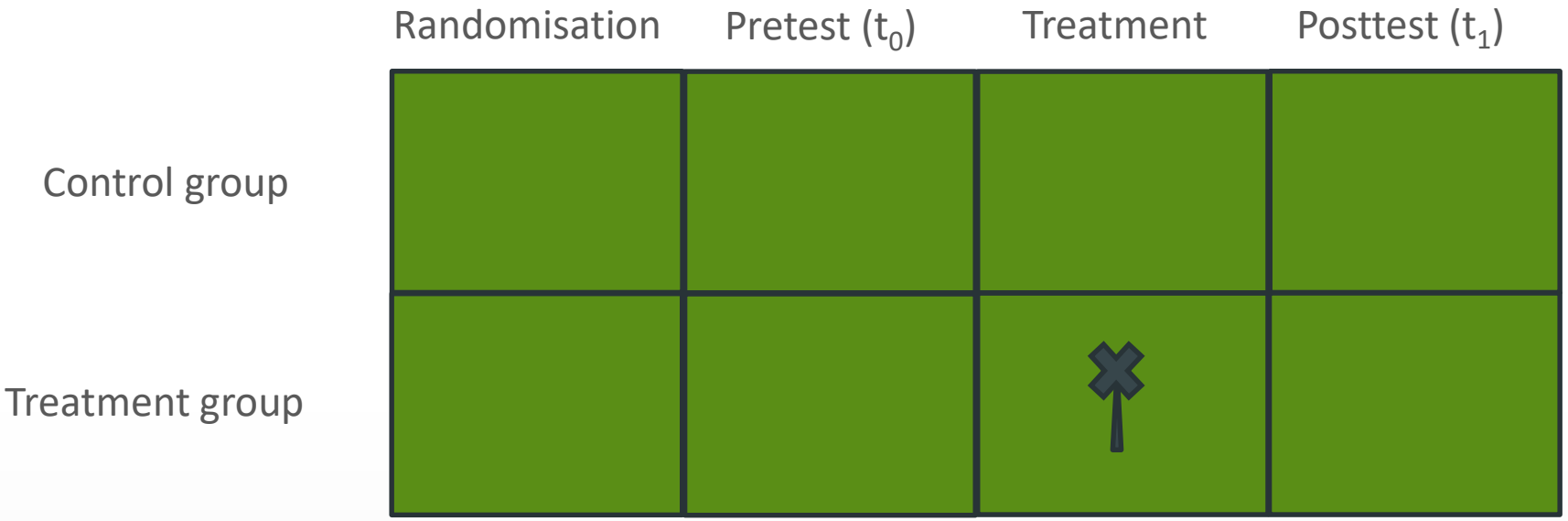
- Severe chronic insomnia
- Increased risk of cardiovascular disease
- "Continuous exposure leads to sensitization, not habituation." (Mathys W et al. Commentary on "Windenergieanlagen…" Deutsche Medzinische Wochenschrift 2022: 1220-1221)

- reduced ability to concentrate
- Performance reductions
- psycho-vegetative disorders

(UBA 2016; Krahé et al. 2014 und 2020).

Source: https://www.vernunftkraft.de/mythos-8/

Ideally, we'd like an experimental setting …



- Does the health of individuals in the treatment group differ from the health of individuals in the control group in t_1?

Data (1): The German Socio-economic Panel (SOEP)

- Representative microdata collected annually since 1984 on approximately 30k people in 11k households and families in Germany (38 waves now available)
- Measures stability and changes in living conditions
  - primarily microeconomic but enriched with sociological and political variables, primarily from the “social indicator movement”
  - objective indicators (e.g. income, employment status, assets, consumption, housing)
  - subjective indicators (e.g. life satisfaction, concerns about climate and environment)
- Paradata: living environment and exact interview date
- Since 2000: Geo-referenced addresses
  - On your own PC (subject to agreeing a data protection concept between your institute and SOEP group): spatial planning regions and classifications
  - Remote: Submitting do-files for analyzing e.g. INKAR data at district level
  - On site (1): Bring your own data at e.g. zip code or municipality level
  - On site (2): Bring your own POI data to calculate your own indicators using coordinates

Data (2): Dependent variables

- Psychological Component Summary (MCS) and Physical Component Summary (PCS) of health related quality of life (HRQoL) short form (SF12) of the Health Questionnaire SF36 (SF12v2) (Ware, Kosinski und Keller (1996))
- Surveyed bi-annually since 2002; MCS and PCS are provided. Norm-based scoring (German population 2004): Mean 50, SD 10 (Nübling, Andersen, Mühlbacher, Schupp und Wagner 2007)
- SOEP has also been surveying chronic diseases biannually since 2009. Issue: in 2009 there are already a lot of WT near the SOEP locations considered here.

SF12 items in SOEP:

General health status
Impairment when climbing stairs due to health conditions
Impairment in other strenuous activities in everyday life
In the last 4 weeks, how often
felt depressed or sad
felt calm and balanced
felt a lot of energy
had severe physical pain
accomplished less in everyday life because of physical health
restricted in type of activity due to physical constraints
achieved less because of mental or emotional problems
been less careful than usual because of mental or emotional problems
restricted in social contacts

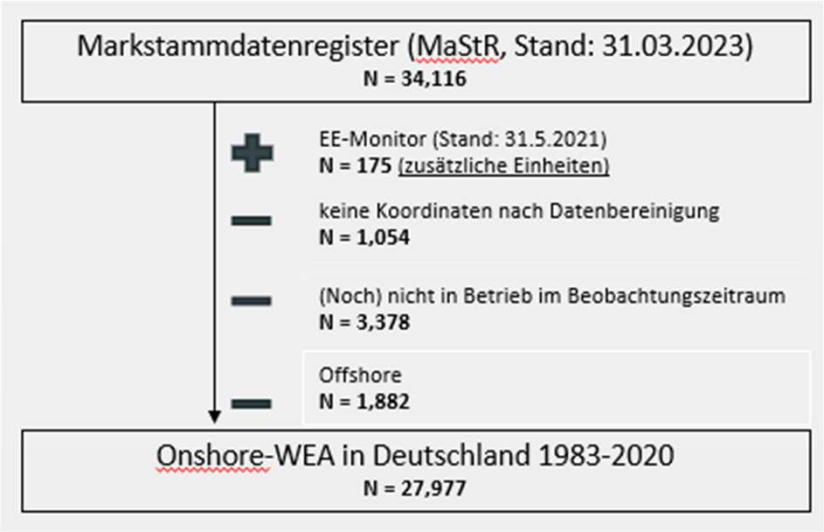
Data (3): Wind turbine Treatment

WT Treatment $\begin{cases} 0, \text{ if no wind turbine within radius } r \text{ km from home address} \\ 1, \text{ if wind turbine(s) within radius } r \text{ km from home address} \end{cases}$

with r =[1 (0.5) 5]

Marktstammdatenregister (MaStR)

- Official register; not created as a panel data set; significant data gaps
- Manual correction of suspicious entries
- Additionally: Comparison with the Renewable Energy Monitor (EE Monitor) of the Center for Environmental Research (Date: May 2021)



https://www.marktstammdatenregister.de/MaStRHilfe/subpages/dokumentendownload.html

Data (4): Allocation to treatment and control group

- Focus on SOEP waves with relevant info (2002-2020)
- Tagging WT active at time of the individual interview
- Compute distances to WT:
  - For both groups:
    - no WT in 0-10 km t_0
    - no residential relocation t_0 to t_1
  - Treatment group, if:
    - WT in r= 1 (0.5) 5 km in t_1
  - Control group if:
    - no WT in 0-10 km in t_1
    - WT in 10-15 km in t_1

Available ‚real' coordinates for SOEP households (v37)
Households = 551,424

− not 2002-2020, no coordinates, no WT in 15 km radius
N = 65,146

Cleaned gross analysis sample
Households = 486,278 with **83,635 interviewees**

− Ever had WT in 10 km radius; no MCS/PCS; no WT built between t_0 und t_1 or WT built in buffer zone 5-10 km; Move between SF12 measures; no „statististical twin " available in Propensity Score Matching, etc.
Individuals = 82,151

$N_{r=5}$ =2,968	$N_{r=1}$ =124
Individuals: 1,484	Individuals: 62
Treatment and control: 742	Treatment and control: 31

Empirical model (1): Difference-in-Differences estimator

- „Fixed Effects“ estimator:

$$y_{it} = \alpha + \beta_1 WT_t + \sum_{t=2}^{T} \beta_t Year_t + \gamma X_{it} + \varepsilon_{it}$$

with treatment dummy WT, Year dummies, and error term ε

- β_1 shows the effect of treatment (WT_1 = 1 for all treated cases and 0 for all control cases)
- Focus on non-movers means that time-invariant individual and neighbourhood fixed effects get absorbed in β_1
- individual characteristics (X_{it}) can be integrated

Empirical model (2): Propensity Score Matching

- Treatment and control groups should not differ at time t_0 (parallel trends assumption)

- Formally not testable; Alignment via PSM on traits affecting SF12
    - age group, gender
    - number of hospital visits previous year
    - number of doctoral visits last three months
    - Living in a residential area
    - % of area used for traffic infrastructure (current and last year)
    - Typology of rural areas (“Thünen typology”)

- Generally speaking, no strong biases in these characteristics, but varies across samples.

Fixed effects panel regressions of SF12 on wind turbine presence: quasi-experimental sample

		All WT			Big WT only		
		β_1	SE	N	β_1	SE	N
Mental health (MCS)							
radius	5 km	-0.39	0.333	1,484	-0.18	0.344	1382
	4.5 km	-0.61	0.367	1,238	-0.42	0.380	1152
	4 km	-0.37	0.415	980	-0.08	0.432	904
	3.5 km	-0.05	0.492	676	-0.02	0.517	628
	3 km	-0.58	0.621	454	-0.56	0.659	426
	2.5 km	-0.16	0.779	268	-0.35	0.812	232
	2 km	-0.04	1.004	198	-0.91	1.104	154
	1.5 km	0.83	1.286	122	1.39	1.460	82
	1 km	1.46	2.187	62	2.53	2.921	36
Physical health (PCS)							
radius	5 km	-0.62*	0.280	1,484	-0.68*	0.290	1382
	4.5 km	-0.52	0.310	1,238	-0.62	0.322	1152
	4 km	-0.51	0.357	980	-0.61	0.367	904
	3.5 km	-0.24	0.440	676	-0.33	0.443	628
	3 km	-0.19	0.561	454	-0.13	0.546	426
	2.5 km	-0.84	0.743	268	-0.36	0.704	232
	2 km	-0.78	0.941	198	-0.05	0.957	154
	1.5 km	-1.81	1.212	122	-1.63	1.210	82
	1 km	-1.49	2.022	62	-1.37	2.073	36

Source: SOEP 2002-2020 (v37) linked to MaSTR (Date: 31.03.2023) with own corrections.

Fixed effects panel regressions of SF12 on wind turbine presence: non q-exp sample

		All WT	Big WT only
Physical health (PCS)			
radius	5 km	-1.79***	-1.75***
	4 km	-1.75***	-1.74***
	3 km	-1.58***	-1.62***
	2 km	-1.41***	-1.53***
	1 km	-1.01**	-1.23***
full set of controls			
radius	5 km	-0.19*	-0.21*
	4 km	-0.23*	-0.25*
	3 km	-0.12	-0.17
	2 km	0.01	-0.08
	1 km	0.39	0.25

- No effects for MCS

Source: SOEP 2002-2020 (v37) linked to MaSTR (Date: 31.03.2023) with own corrections.
Note: Only the b-coefficients are displayed. Robust standard errors and sample sizes have not yet been extracted from the log files due to file length and time constraints. For control variables, see page 19.

Summary and conclusions

- V strong negative associations between presence of wind turbines in 1-5 km radius around the home and PCS; likely driven by residential selection but robust to individual, household and neighbourhood characteristics
- much smaller effect in quasi-experimental sample and statistically significant only in 5km radius. Likely sample size issue.
- (causal-) effect very difficult to identify empirically; unclear which causal mechanism(s) at play

- Krekel et al. 2023 DIW Discussion Paper uses WT data until 2017 only and find no effect of WT on any health measures in a 4km radius. The jury is still out!

Empirical model (3): Propensity Score Matching (2)

Variable	Unmatched / Matched	Mean: Treated	Mean: Control	%bias	%reduct |bias|	V_e(T)/ V_e(C)
Age group						
24-29	U	0.05	0.06	-7.2		0.76*
	M	0.05	0.03	7.2	1	1.38*
30-44	U	0.29	0.31	-4.6		0.94
	M	0.29	0.31	-5.9	-29	0.95
45-59	U	0.32	0.28	8.9		1.06
	M	0.32	0.31	2.9	67	1.05
60 or older	U	0.26	0.27	-0.6		1.00
	M	0.26	0.26	0	100	1.00
Female	U	0.52	0.52	-1.7		1.00
	M	0.52	0.52	0	100	1.00
Hospital visits (last year)						
1-7 nights	U	0.07	0.07	-0.7		0.97
	M	0.07	0.08	-3.2	-330	0.91
8-14 nights	U	0.03	0.03	1.9		1.12
	M	0.03	0.03	1.6	16	1.11
more than 14 nights	U	0.02	0.02	-0.3		0.98
	M	0.02	0.02	0	100	1.00
Doctoral visits						
1-2 appointments	U	0.39	0.37	4.5		1.02
	M	0.39	0.39	1.4	69	1.02
3-5 appointments	U	0.20	0.22	-4		0.95
	M	0.20	0.21	-3	26	0.97
> 5 appointments	U	0.10	0.10	-1.1		0.97
	M	0.10	0.11	-2.7	-134	0.93

* if 'of concern', i.e. variance ratio in [0.5, 0.8) or (1.25, 2]

** if 'bad', i.e. variance ratio <0.5 or >2

Empirical model (4): Propensity Score Matching (3)

Variable	Unmatched / Matched	Mean: Treated	Mean: Control	%bias	%reduct |bias|	V_e(T)/ V_e(C)
Residential area	U	0.79	0.75	10.6		0.89
	M	0.79	0.81	-4.2	61	1.11
% area used for traffic						
current year	U	4.94	5.39	-17		0.70*
	M	4.95	5.02	-2.6	85	0.85
last year	U	4.91	5.35	-16.8		0.70*
	M	4.91	4.98	-2.6	85	0.85
Typology of rural areas						
very rural, soc-econ. not so good	U	0.15	0.13	6.4		1.19
	M	0.15	0.13	3.9	39	1.04
very rural, soc-econ. good	U	0.04	0.10	-23.8		0.60*
	M	0.04	0.04	1.6	94	1.12
rather rural, soc-econ. good	U	0.16	0.14	5.9		1.17
	M	0.16	0.16	0	100	1.00
rather rural, soc-econ. not so good	U	0.18	0.09	24.9		1.15
	M	0.18	0.17	0.8	97	1.01

* if 'of concern', i.e. variance ratio in [0.5, 0.8) or (1.25, 2]

** if 'bad', i.e. variance ratio <0.5 or >2

Characteristics of quasi-experimental sample

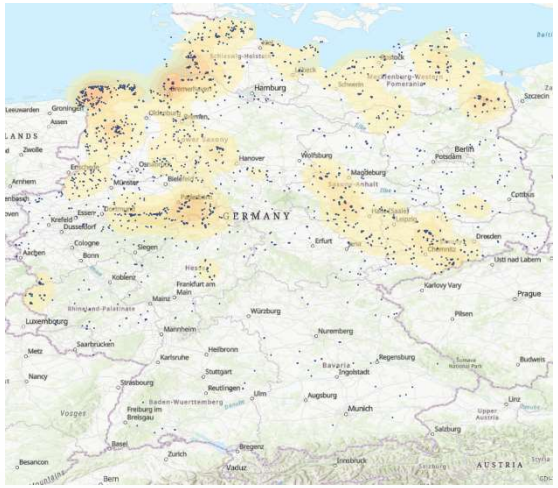
(NB. 5km radius; samples vary by treatment radius)

	Estimation sample (N=2968)				
	mean	**median**	**min**	**max**	**cv**
MCS	50.88	52.26	10.97	75.54	0.19
PCS	49.57	51.94	12.64	69.59	0.20
Age	49.49	49	17	97	0.32
Female	0.52	1	0	1	0.97
married	0.65	1	0	1	0.73
single	0.19	0	0	1	2.05
widowed	0.04	0	0	1	4.65
separated	0.11	0	0	1	2.84
no children in hh	0.65	1	0	1	0.73
primary edu or less	0.14	0	0	1	2.45
secondary edu	0.56	1	0	1	0.88
tertiary education	0.29	0	0	1	1.55
full-time empl.	0.42	0	0	1	1.18
part-time empl.	0.13	0	0	1	2.57
still in education	0.02	0	0	1	6.96
irreg. empl.	0.05	0	0	1	4.56
not employed	0.38	0	0	1	1.27
Owner	0.54	1	0	1	0.92
Ø monthly personal income (net.)	1335	843	0	37748	1.41
Ø monthly household income (net.)	3717	3096	374	50583	0.75
# sq metres per person	44.60	38.00	11.33	190.00	0.53

SOEP „blind spots“ by design

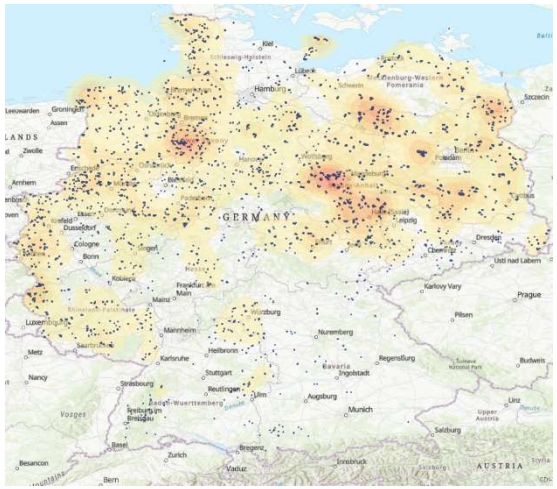
Wind turbines in Germany 1983-1999, 2000-2001, 2002-2008

1983 to end of1999 (new: 3,345)



2000 to end of 2001 (new: 3,148)

2002 to end of 2008 (new: 8,406)



Source: MaSTR (Date: 31.03.2023) with own edits.

- No address information until 2000
- no SF12 until 2002
- No chronic disease measurement until 2009