Study on the Wind Power Potential in Bulgaria, Hungary and Romania (funded by ECF)

On behalf of:: European Climate Foundation

General approach and results

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Goal of the study:

This study aims to shed light on the applicable potentials for wind power development (onshore & offshore) in Bulgaria, Hungary and Romania, indicating how wind power may contribute to meet the future demand for electricity in a carbon-neutral manner

Approach:

→ A **detailed GIS-based analysis** of the potential for wind power development, building on:

- **a comprehensive meteorological dataset at a high geographical resolution**
  *Data source: COSMO-REA6 (1995-2018), 100m*100m grid layer*
- **incorporating spatial constraints** related to competing land use (nature protection, urban, agriculture, forestry, military use or other purposes that limit the suitability for wind power and related grid development)
  Data source: CORINE land use database (2021)
- **Sensitivity analyses for key input parameter** (incl. **distance rules, turbine design** or **economic limits**).
- **Mapping exercise** to indicate the match with the **grid infrastructure**

→ *Complementary assessment of **electricity market impacts of an enhanced wind deployment** (@REKK)*

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Key assumptions for the GIS-based assessment of wind potentials:

Wind turbine specification (default onshore turbine)	
Generator size	4.95 MW
Rotor diameter	163m
Area for one turbine	0.54 km²
MW per km²	9.2 MW/km²

Land use category	Average suitability factor
Built environment, Inland waters	0%
Agricultural areas	40%
Forestry areas	10%
Wetlands	30%

Details on the approach taken:

- **Matching of wind speed data** with wind turbine **power curve** → **Load factors** (full load hours) **by pixel**
- **Consideration of distance rules to the built environment,** e.g., 1.2 km to housing, etc.
- **Exclusion** (or illustrative inclusion) of **nature protection areas and other land use categories** (e.g., built environment, inland waters, etc.)

⇨ Technical potentials w/o land use constraints

- **Application of further land use restrictions:**

⇨ Technical potentials with land use constraints

- Least-cost allocation: Preference to best sites within a region
- Balanced allocation: Balanced allocation of wind sites (i.e., using average suitability factors)

Study on the Wind Power Potential: Romania

Onshore wind

On behalf of:: European Climate Foundation

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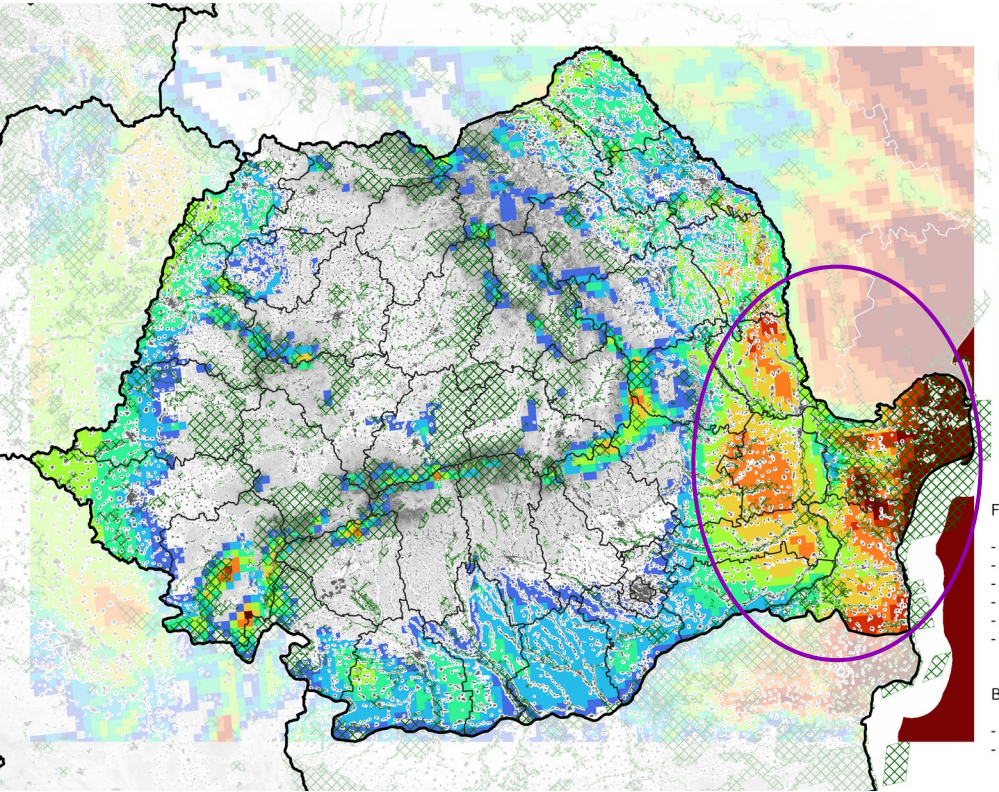
Calculated wind potential map: Romania

Remark: Protected areas included in graphical depiction



Boundaries
- Country borders
- Other countries
- NUTS-3 regions
- Protected areas (WDPA Jun2023)

FLH
- <= 1800 FLH
- 1800 - 2000 FLH
- 2000 - 2200 FLH
- 2200 - 2400 FLH
- 2400 - 2600 FLH
- 2600 - 2800 FLH
- 2800 - 3000 FLH
- > 3000 FLH

FLH calculated from COSMO-REA6 data, assumin

- turbine N163-4.95 (150 m hub height)
- overall efficiency 85%
- SRTM >2000m height and >20% slope excluded
- protected areas (WDPA) not excluded
- CLC: built-up areas + 1200 m buffer excluded
- other land use restrictions: see documentation

Base map:

- CORINE Land Cover (CLC)
- SRTM DEM overlay (mountains are more black)

	Area potential: total usable area [ha]	Technical potential w/o land use constraints: Capacity potential [MW]	Energy potential [GWh]	Average full load hours [h/a]
Excl. Nature Protection Areas	5,421,656	498,812	1,047,422	2,100
Incl. Nature Protection Areas	8,524,566	784,291	1,679,550	2,141

Technical potential with land use constraints (Least-Cost)

Scenario	Capacity potential [MW]	Energy potential [GWh]	Average full load hours [h/a]
Excl. Nature Protection Areas	166,463	364,098	2,187
Incl. Nature Protection Areas	240,019	538,079	2,242

Technical potential with land use constraints (Balanced)

Scenario	Capacity potential [MW]	Energy potential [GWh]	Average full load hours [h/a]
Excl. Nature Protection Areas	166,764	354,734	2,127
Incl. Nature Protection Areas	234,196	506,369	2,162

Study on the Wind Power Potential: Romania

Onshore wind

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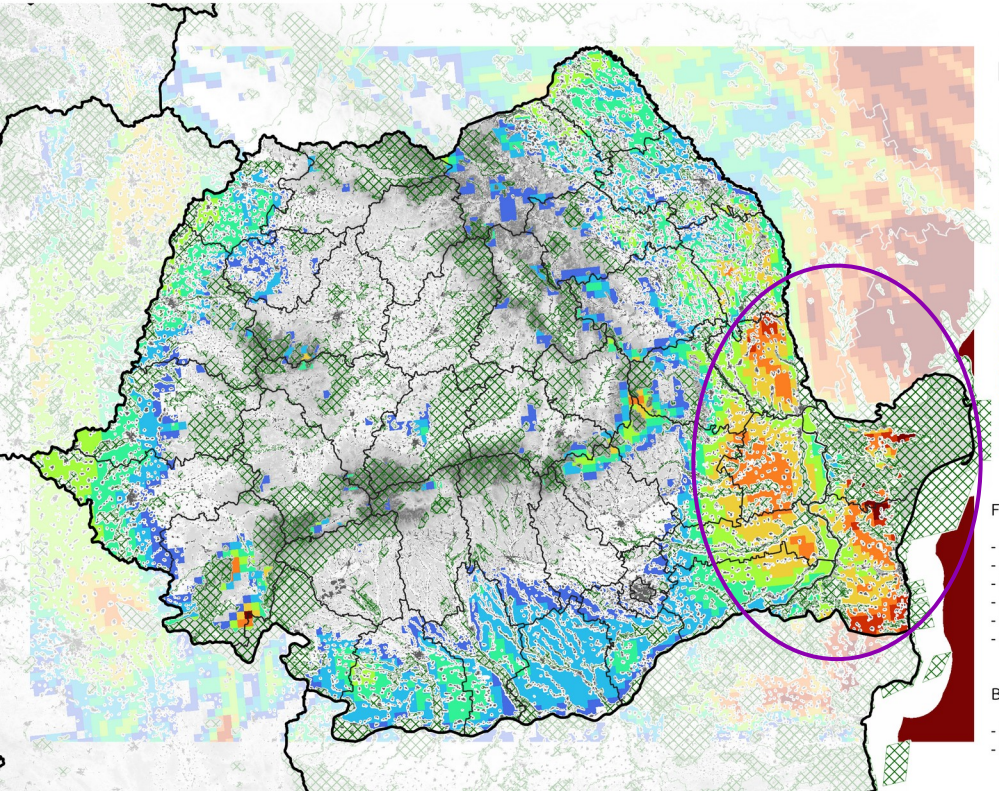
Calculated wind potential map: Romania

Remark: Protected areas excluded in graphical depiction



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Study on the Wind Power Potential:
Romania: Details by region

Onshore wind

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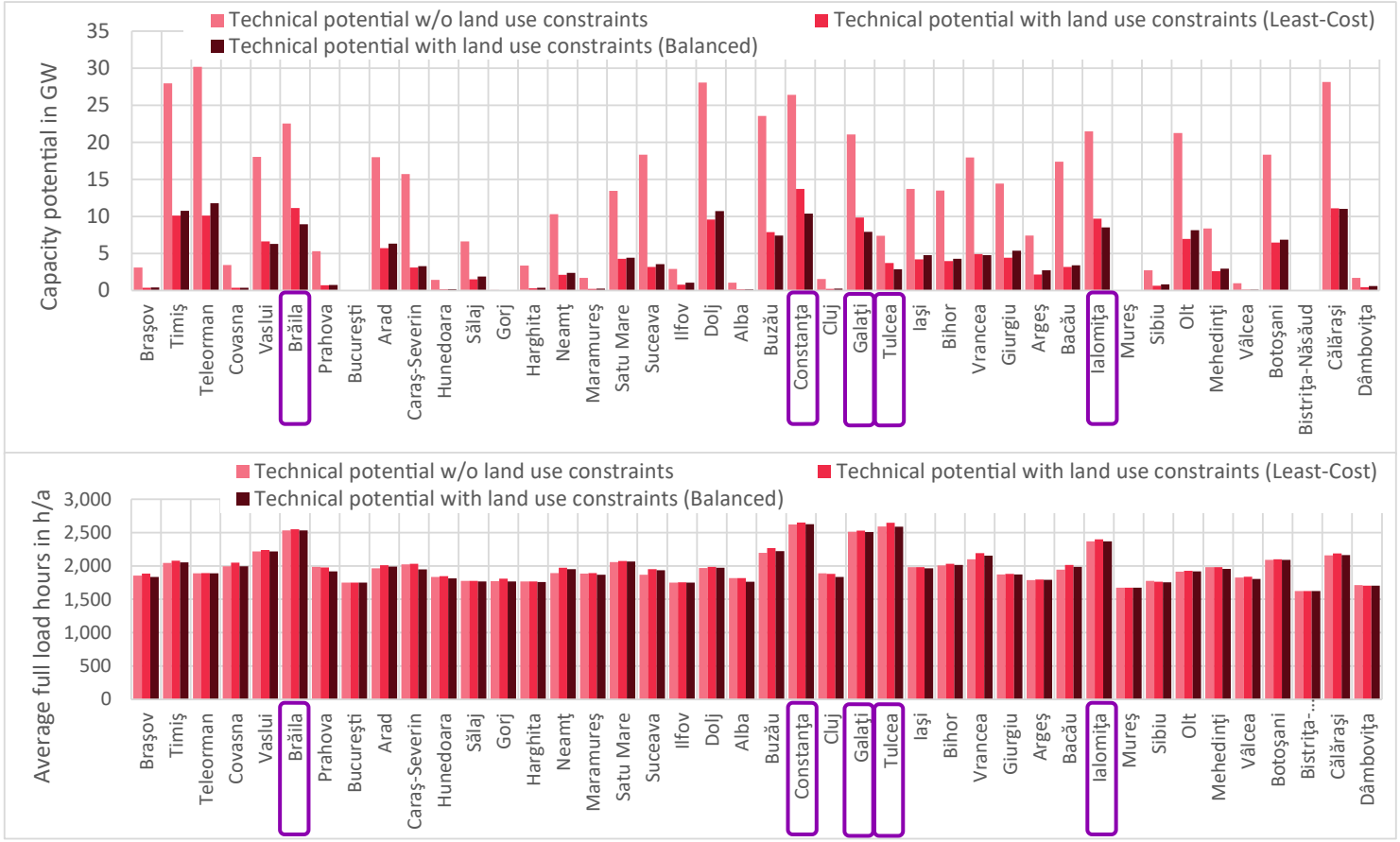

Capacity (top) & **full load hours** (**site quality**) (bottom)

by region

(**excluding nature protection areas**)

Study on the Wind Power Potential:
Romania: Details by region

Onshore wind

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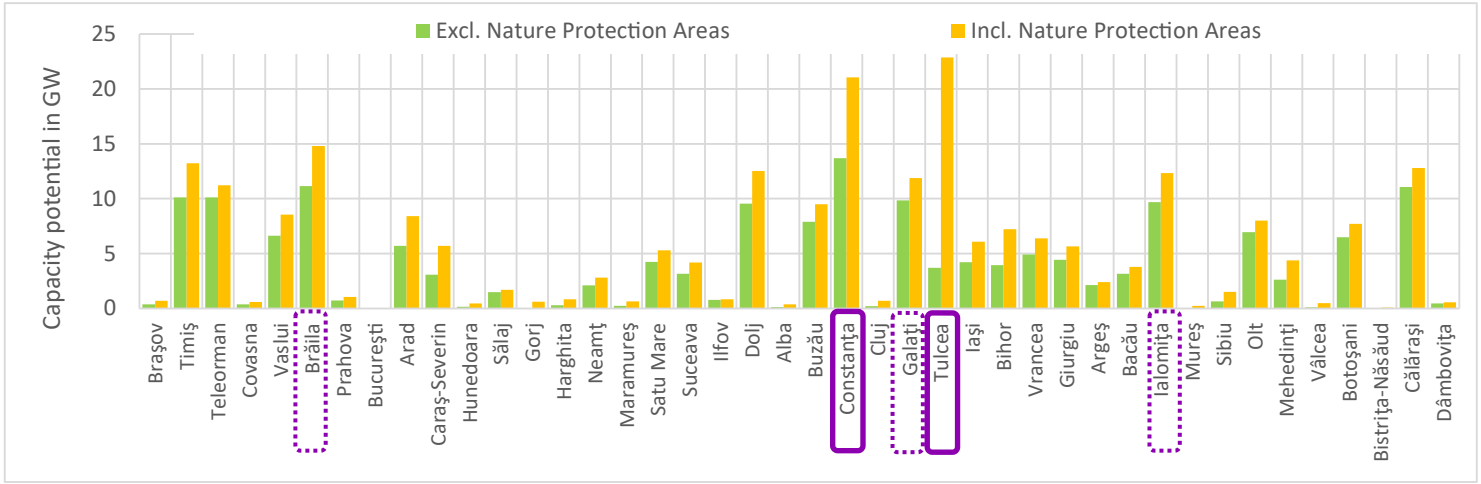

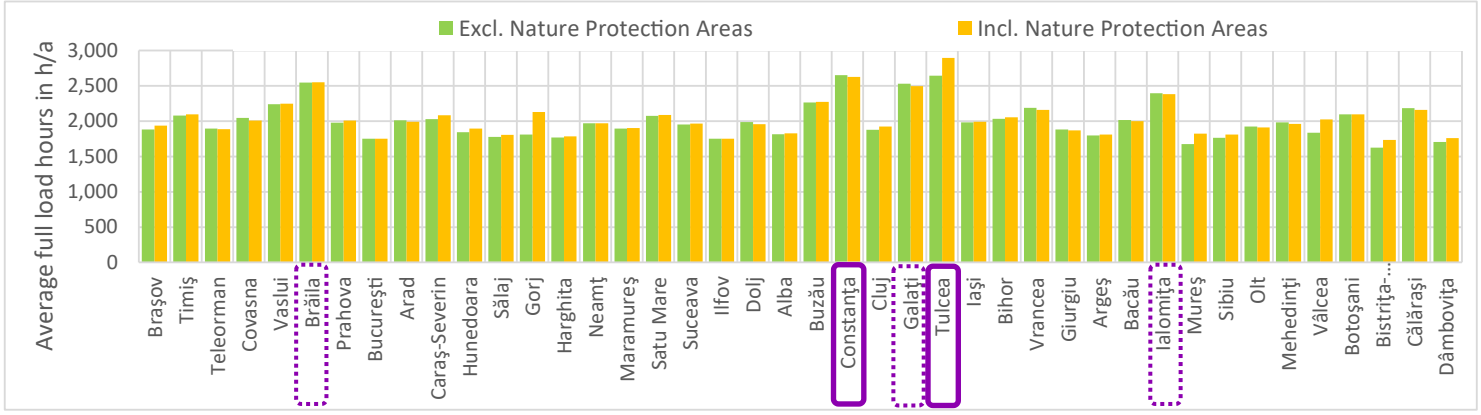

Impact of nature protection:

Technical potentials with land use constraints (least-cost), incl. & excl. nature protection areas

Capacity (top) & **full load hours** (**site quality**) (bottom) by region

Study on the Wind Power Potential:
Hungary

Onshore wind

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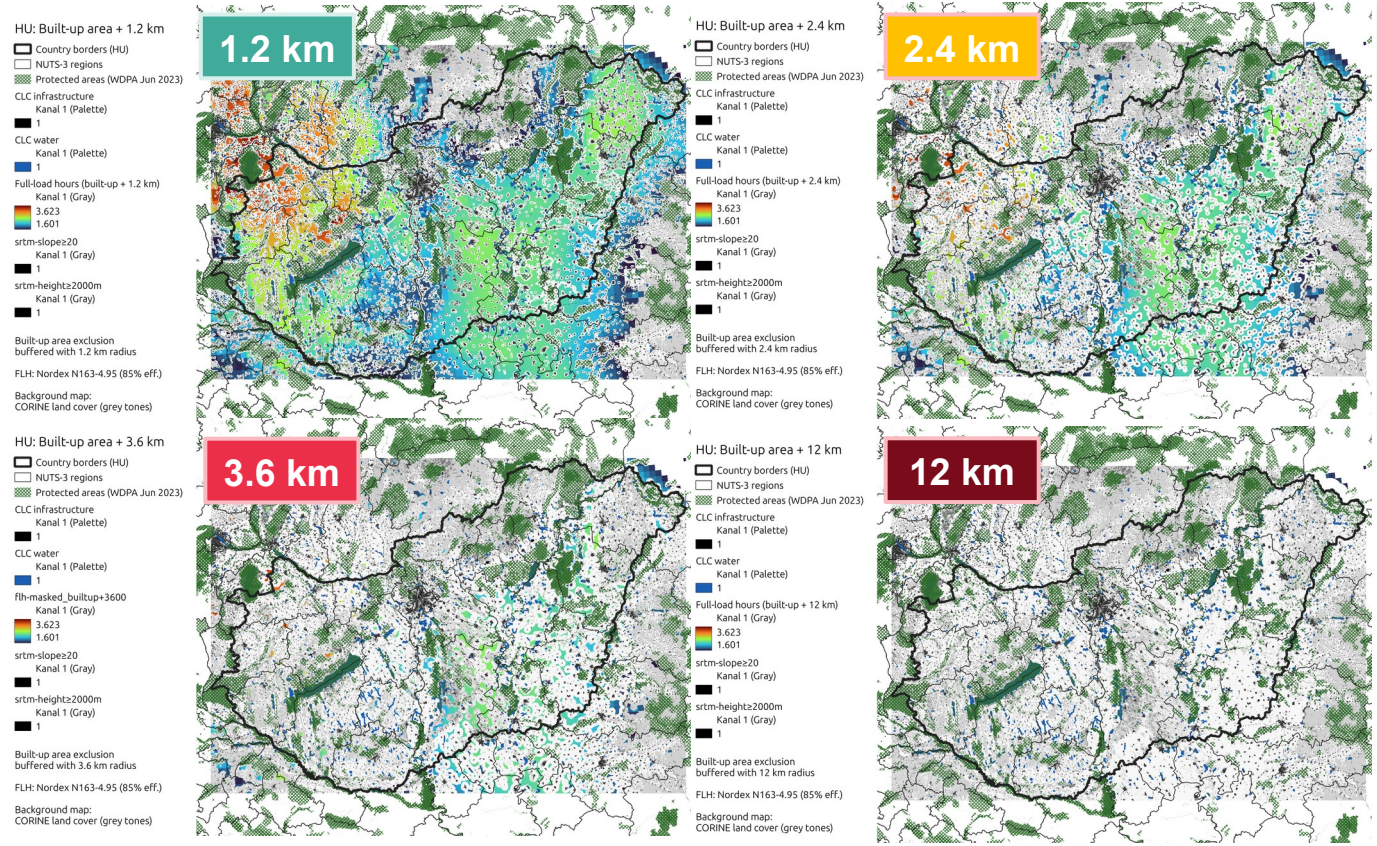
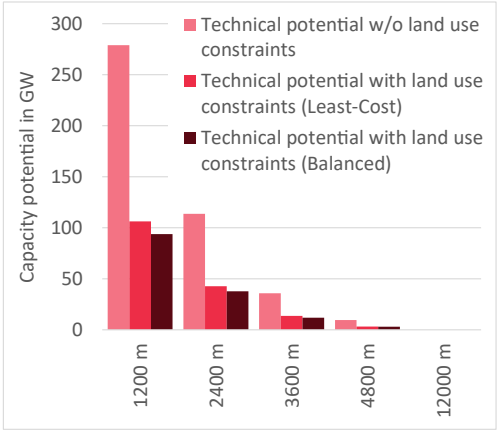
For illustration … Sensitivity assessment: Impact of distance rules on applicable potentials





Conclusion:

With current distance rules, **wind power development is not possible** in Hungary

Study on the Wind Power Potential: Hungary

Onshore wind

On behalf of:: European Climate Foundation

Sensitivity assessment: Impact of distance rules and turbine restrictions on applicable potentials

Comparison: Hungary (total)		Area potential	Technical potential w/o land use constraints			Technical potential with land use constraints (Least-Cost)			Technical potential with land use constraints (Balanced)		
Nature Protection Areas	Distance (to built environment)	total usable area [ha]	Capacity potential [MW]	Energy potential [GWh]	Average full load hours [h/a]	Capacity potential [MW]	Energy potential [GWh]	Average full load hours [h/a]	Capacity potential [MW]	Energy potential [GWh]	Average full load hours [h/a]
Excl. NP	1200 m (default)	3,032,574	279,008	650,883	2,333	106,278	252,821	2,379	93,782	217,621	2,320
Excl. NP	2400 m	1,235,141	113,637	264,987	2,332	42,761	100,604	2,353	37,768	87,419	2,315
Excl. NP	3600 m	388,945	35,784	83,662	2,338	13,627	31,975	2,346	11,950	27,792	2,326
Excl. NP	4800 m	103,721	9,543	22,395	2,347	3,127	7,362	2,354	3,100	7,251	2,339
Excl. NP	12000 m	0	0	0	n.a.	0	0	n.a.	0	0	n.a.
Excl. NP	1200 m - small turbine	2,878,856	264,865	539,466	2,037	81,644	167,923	2,057	87,046	176,430	2,027

→ With current distance rules, **wind power development is not possible** in Hungary

→ Limits on the turbine size have **a negative impact on the viability** and **limit the energetic output**

Study on the Wind Power Potential: Bulgaria

Onshore wind

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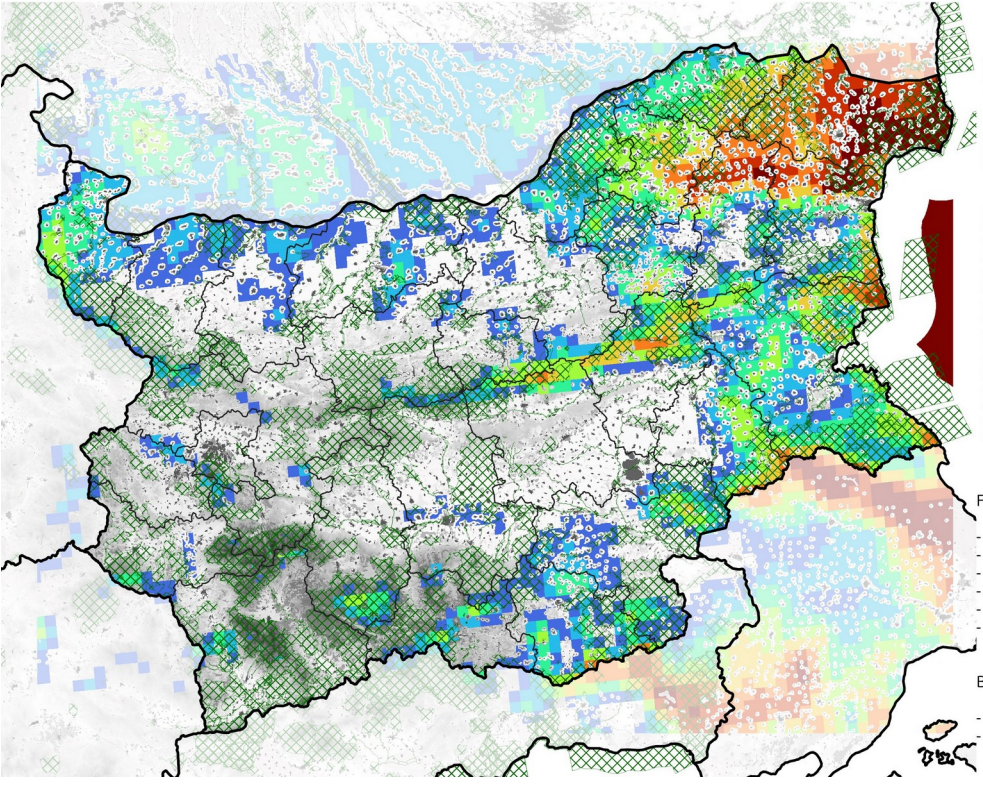
Calculated wind potential map: Bulgaria



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- protected areas (WDPA) not excluded
- CLC: built-up areas + 1200 m buffer excluded
- other land use restrictions: see documentation

Base map:

- CORINE Land Cover (CLC)
- SRTM DEM overlay (mountains are more black)

	Area potential	Technical potential w/o land use constraints		
	total usable area [ha]	Capacity potential [MW]	Energy potential [GWh]	Average full load hours [h/a]
Excl. Nature Protection Areas	1,489,178	137,010	278,468	2,032
Incl. Nature Protection Areas	3,886,827	357,602	745,226	2,084

Technical potential with land use constraints (Least-Cost)			
Scenario	Capacity potential [MW]	Energy potential [GWh]	Average full load hours [h/a]
Excl. Nature Protection Areas	40,440	86,778	2,146
Incl. Nature Protection Areas	93,454	206,911	2,214

Technical potential with land use constraints (Balanced)			
Scenario	Capacity potential [MW]	Energy potential [GWh]	Average full load hours [h/a]
Excl. Nature Protection Areas	42,005	85,709	2,040
Incl. Nature Protection Areas	92,196	193,584	2,100

Study on the Wind Power Potential: Bulgaria and Romania

Offshore wind

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GIS-based analysis of potentials for offshore wind energy

Water depth (z, in m)	Distance to shore (d, in nautic miles)	Country: Bulgaria Area potential (km2)	Bulgaria Capacity potential (MW)	Bulgaria Full load hours (h/a)	Romania Area potential (km2)	Romania Capacity potential (MW)	Romania Full load hours (h/a)
-40 ≤ z	d < 12	0	0		0	0	
	12 ≤ d < 24	1,717	25,216	2,075	530	7,781	2,497
	24 ≤ d	258	3,797	2,557	399	5,859	2,720
-80 ≤ z < -40	d < 12	0	0		0	0	
	12 ≤ d < 24	1,131	16,612	2,445	427	6,278	2,799
	24 ≤ d	1,925	28,274	2,639	9,489	139,378	2,931
-120 ≤ z < -80	d < 12	0	0		0	0	
	12 ≤ d < 24	116	1,707	2,539	0	0	
	24 ≤ d	2,174	31,938	2,662	3,811	55,983	3,031
z < -120	d < 12	0	0		0	0	
	12 ≤ d < 24	9	135	2,414	0	0	
	24 ≤ d	4,654	68,367	2,772	4,521	66,408	2,982
TOTAL Area		34,709			29,587		
USABLE Area		11,985	176,046	2,593	19,177	281,687	2,944

Off-shore wind power potential

- Countries
- EEZ
- Shore distance < 12 km
- Shore distance < 24 km
- Protected areas (WDPA)

FLH
- <= 3229 FLH
- 3229 - 3357 FLH
- 3357 - 3486 FLH
- 3486 - 3614 FLH
- 3614 - 3743 FLH
- 3743 - 3871 FLH
- > 3871 FLH

DEM

Relief

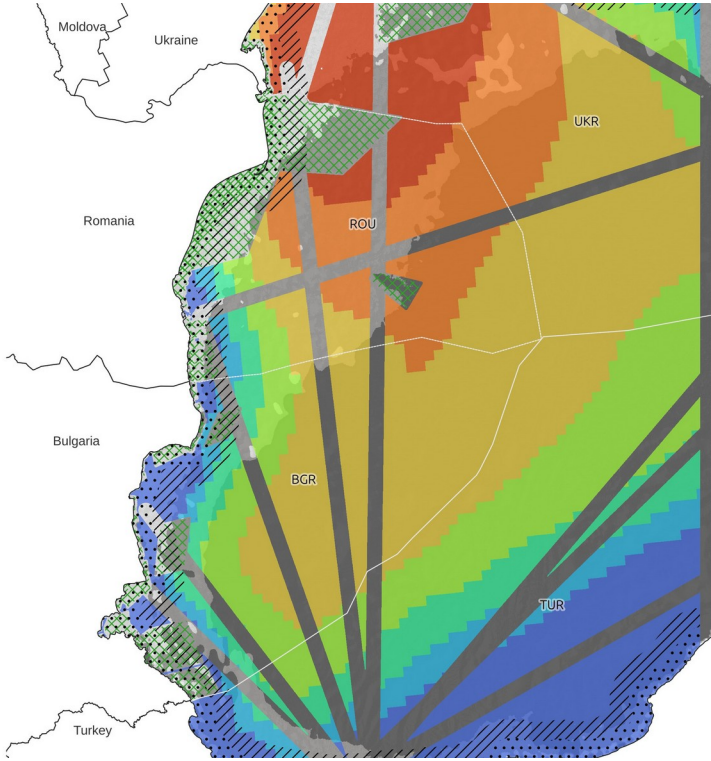
Bathymetry (SRTM15+)
- <= -120 [m]
- -120 - -40 [m]
- -40 - 0 [m]

Wind by COSMO-REA6 (1995 – 2019/08)
Power curve: Nordex N163-4.95
Assumed efficiency: 85%

Excluded areas:
- protected areas (WDPA), buffered with 1.2 km
- shipping routes (manually drawn after real observations)

See documentation for further details.

EPSG:3035 | hirner@bitfire.at | 4 Aug 2023



Study on the Wind Power Potential: A regional perspective

Draft final results

AUSTRIAN INSTITUTE OF TECHNOLOGY

On behalf of:: European Climate Foundation

Wind onshore

	Technical potential with land use constraints (Least-cost), excl. nature protection areas		
	Bulgaria	Hungary	Romania
Capacity (GW)	40.4	106.3	166.5
Generation (TWh)	86.8	252.8	364.1
Full load hours (h/a)	2146	2379	2187

- → **The overall potential for onshore wind is smaller in Bulgaria** compared to Hungary or Romania - **but worth being exploited**
- → **The overall potential for onshore wind in Hungary** is **significant in energetic terms** as well as regarding **site qualities,** worth being exploited
- → In quantitative terms Hungary's potential is larger than in Bulgaria but smaller than in Romania, **reflecting the country size**
- → For offshore wind both Bulgaria and Romania have promising sites at hands

Wind offshore

Bulgaria

	Offshore wind			
	Near/Mid shore, low water depth	Near/Mid shore, low-medium water depth	Far shore, low-medium water depth	High water depth (floating turbines)
Capacity (GW)	25.2	18.3	64.0	68.5
Generation (TWh)	52.3	45.0	169.3	189.8
Full load hours (h/a)	2075	2454	2645	2771

Romania

	Offshore wind			
	Near/Mid shore, low water depth	Near/Mid shore, low-medium water depth	Far shore, low-medium water depth	High water depth (floating turbines)
Capacity (GW)	7.8	6.3	201.2	66.4
Generation (TWh)	19.4	17.6	594.1	198.0
Full load hours (h/a)	2497	2799	2953	2982

Study on the Wind Power Potential: A regional perspective

Wind onshore

Draft final results

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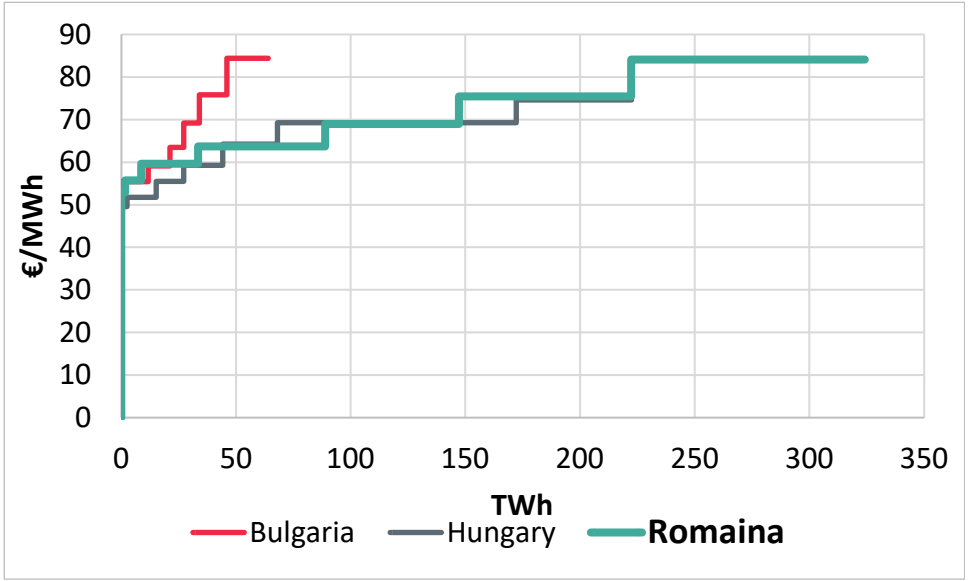

Figure: Cost-resource curves of wind onshore in the study region
(using technical least-cost potentials with consideration of land use constraints)

Assumptions: Investment cost: 1500 EU/kW, 3% O&M cost, Interest rate 6.5%, Depreciation time 20 years

→ **The overall potential for onshore wind in Romania** is **significant in energetic terms** and good regarding **site qualities,** worth being exploited

→ Thus, **considering economics** (cf. cost resource curve) **wind appears being a viable electricity generation option for Romania**

Study on the Wind Power Potential: Bulgaria

Wind on- & offshore

Draft final results

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NECP targets

		Current planning	New 2030 EU target (w/o top-up)	New 2030 EU target (with top-up)
Planned 2030 RE share in GFEC	%	27.1	35.1	37.3
Planned 2030 RE share in gross electricity demand	%	30.3	39.3	41.8
Planned 2030 RE electricity generation	TWh	42.98	55.7	59.2
Planned 2030 wind generation	TWh	2.05	2.7	2.8
Planned 2040 wind generation (Reference)	TWh	3.61	4.7	5.0

Summary of identified wind potentials

Technology		Onshore wind				Offshore wind			
Type of potential		Technical potential with land use constraints (Least-cost), incl. nature protection areas	Technical potential with land use constraints (Balanced), incl. nature protection areas	Technical potential with land use constraints (Least-cost), excl. nature protection areas	Technical potential with land use constraints (Balanced), excl. nature protection areas	Near/Mid shore, low water depth	Near/Mid shore, low-medium water depth	Far shore, low-medium water depth	High water depth (floating turbines)
Installed capacity	GW	93.5	92.2	40.4	42.0	25.2	18.3	64.0	68.5
Electricity generation	TWh	206.9	193.6	86.8	85.7	52.3	45.0	169.3	189.8
Full load hours	h/a	2214	2100	2146	2040	2075	2454	2645	2771

→ **Wind energy has the potential to take a prominent role in Bulgaria's future electricity supply,** by far exceeding current energy and climate planning

Study on the Wind Power Potential: Hungary

Wind onshore

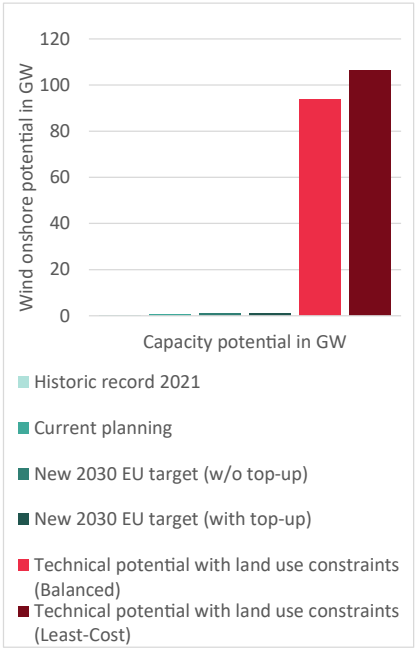
On behalf of:: European Climate Foundation

NECP targets

		Current planning	New 2030 EU target (w/o top-up)	New 2030 EU target (with top-up)
Planned 2030 RE share in GFEC	%	21.0	33.4	35.7
Planned 2030 RE share in gross electricity demand	%	21.3	33.9	36.2
Planned 2030 RE electricity generation	TWh	11.29	18.0	19.2
Planned 2030 wind generation	TWh	0.69	*1.1*	*1.2*
Planned 2030 wind capacity	GW	0.33	*0.5*	*0.6*

Summary of identified wind potentials

Technology		Onshore wind	Onshore wind	Onshore wind	Onshore wind
Type of potential		Technical potential with land use constraints (Least-cost), incl. nature protection areas	Technical potential with land use constraints (Balanced), incl. nature protection areas	Technical potential with land use constraints (Least-cost), excl. nature protection areas	Technical potential with land use constraints (Balanced), excl. nature protection areas
Installed capacity	GW	178.5	156.6	106.3	93.8
Electricity generation	TWh	424.9	362.1	252.8	217.6
Full load hours	h/a	2380	2312	2379	2320



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Study on the Wind Power Potential: Romania

Wind total

On behalf of:: European Climate Foundation

NECP targets

		Current planning	New 2030 EU target (w/o top-up)	New 2030 EU target (with top-up)
Planned 2030 RE share in GFEC	%	30.7	42.4	44.5
Planned 2030 RE share in gross electricity demand	%	49.4	68.2	71.6
Planned 2030 RE electricity generation	TWh	36.93	51.0	53.5
Planned 2030 wind generation	TWh	11.69	16.1	16.9
Planned 2030 wind capacity	GW	5.26	7.3	7.6

Summary of identified wind potentials

Technology		Onshore wind				Offshore wind			
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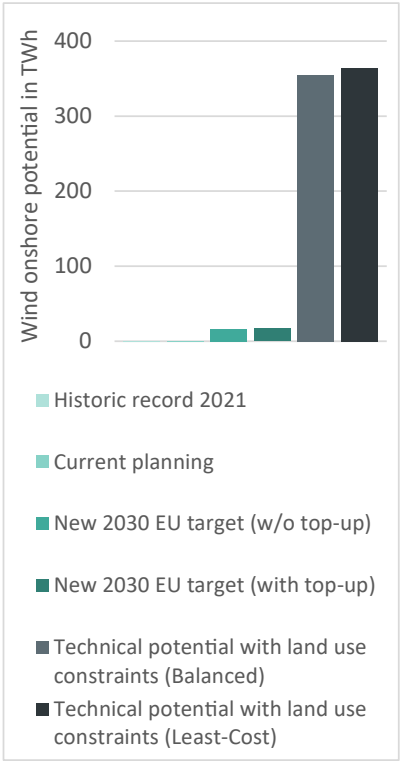
Installed capacity	GW	240.0	234.2	166.5	166.8	7.2	6.9	156.3	104.3
Electricity generation	TWh	538.1	506.4	364.1	354.7	17.6	19.3	463.3	308.8
Full load hours	h/a	2242	2162	2187	2127	2458	2805	2965	2959



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On behalf of::

Many thanks for your attention!

lukas.liebmann@ait.ac.at