In it together: the road to a cleaner, cheaper CEE power system

Central and Eastern European countries could increase security and lower power prices through regional collaboration and more wind and solar.

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About

In this report, Ember proposes an ambitious wind and solar expansion plan for Central and Eastern European (CEE) countries: Estonia, Latvia, Lithuania, Poland, Czechia, Slovakia, Hungary, Slovenia, Croatia, Bulgaria, Romania. It shows that accelerated renewables deployment can lead to improved security and lower power prices. The study uses a newly developed open model of the European power market.

Highlights

-29%

Additional wind and solar capacity will lower CEE power prices by 29%

200 GW

CEE countries could deliver 200 GW of wind and solar by 2030

100 GW

Regional collaboration could open up over 100 GW of offshore wind potential

Executive Summary

CEE countries can increase security through accelerating wind and solar

The region should set ambitious wind and solar targets for 2030 to reduce electricity prices and become more competitive.

Central and Eastern European (CEE) countries (Estonia, Latvia, Lithuania, Poland, Czechia, Slovakia, Hungary, Slovenia, Croatia, Romania and Bulgaria), have made significant improvements to their energy transition in recent years. The region covers roughly 20% of the EU population and territory, 15% of the EU's GDP and 17% of the electricity demand, but still accounts for just 7% and 12% of EU wind and solar capacity, respectively. However, current renewables targets in most CEE countries are significantly below EU averages. This hesitant approach to wind and solar deployment, combined with continued high reliance on fossil fuels, is now posing a threat to the region's energy security, increasing the cost of living and reducing the competitiveness of economies.

Modelling a higher ambition approach to renewables through 2030 shows that a different path brings big benefits. If CEE countries take advantage of their wind and solar potential by removing barriers to renewables deployment, 2030 wholesale power prices drop 29% compared to a pathway under current policy conditions. This would not only make the region much more competitive in Europe, it would also improve energy security.

Important milestones approach for CEE countries energy planning: including the process of updating National Energy and Climate Plans (NECPs), due by mid-2023, and the required inclusion of REPowerEU chapters in Recovery and Resilience Plans (RRP) in Q2 2023. To access the full benefits of cheap renewable energy, CEE countries should take the opportunity to propose ambitious decarbonization pathways.

01 Additional wind and solar capacity will lower CEE power prices by 29%

By pursuing more ambitious wind and solar deployment, the CEE region can lower average wholesale electricity prices by 29% compared to current policy ambition. The region can also become fully sufficient in terms of electricity production, exporting 23.1 TWh of electricity in 2030, compared to importing 7.3 TWh in 2022. If the region fails to take part in Europe's energy transition, it will lose economic competitiveness and become reliant on electricity imports.

02 CEE countries can deliver 200 GW of wind and solar by 2030

The CEE region can deploy 130 GW of solar, 45 GW of onshore wind and 20 GW of offshore wind capacity by 2030, a six-fold increase from the current wind and solar capacity of 35 GW and almost twice what is likely with the current policy context. This would allow the CEE region to reach a 63% share of renewables in electricity generation by 2030, compared to just 25% in 2022, making the EU's 2040 net zero power system achievable.

03 Collaboration is necessary to unlock the region's full potential

Only cross-country collaboration can unlock the region's over 100 GW of offshore wind potential. Accelerating existing and discussed interconnection projects allows for better integration of wind and solar, reducing electricity curtailment and power prices.

04 Aligning national renewable strategies with EU's policy opens up at least €136 billion in public funding

Setting renewables targets in line with EU climate policy would open up at least €136 billion in EU funding for CEE's energy transition from the Recovery and Resilience Facility, Just Transition Fund and Modernization Fund.

"This report shows what's possible for Central and Eastern Europe: a thriving, connected region powered by bountiful wind and solar. Not only will wind and solar bring economic benefits, but they are also an absolutely crucial tool to build energy security given the region's history and close proximity to Russia. CEE needs to channel the clean power momentum sweeping across Europe, failing to do so will have dire economic and security consequences."

Dr Paweł Czyżak
Senior Energy & Climate Data Analyst,
Ember

Wind and solar in CEE

More wind and solar brings benefits, building less brings risks

CEE countries can increase wind and solar capacity six-fold by 2030, increasing economic competitiveness and reducing energy security risks.

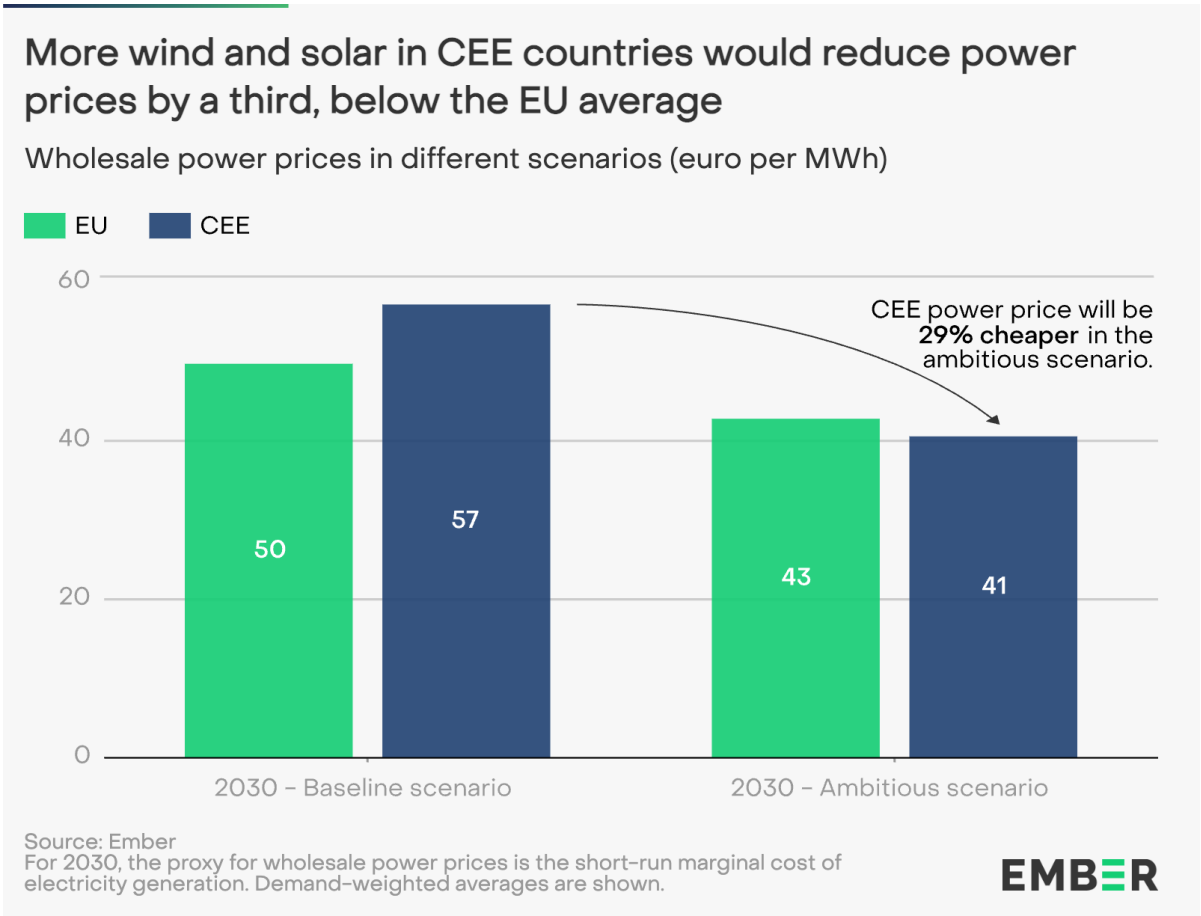
Additional wind and solar capacity will lower CEE power prices by 29%

Central and Eastern European (CEE) countries have experienced a recent solar power boom, exceeding forecasts and reaching solar generation records. However, the biggest electricity consumers in the region — Poland, Czechia, Romania and Hungary — are still hesitant to set ambitious renewables targets, relying on expensive coal and gas. They also face some of the highest electricity prices in Europe. As a whole, the CEE region's current energy strategy is still heavily reliant on fossil fuels, with significant risks to energy security and economic competitiveness.

However, different paths are available. With barriers to renewables deployment removed, the region could take full advantage of wind and solar potential, and see corresponding benefits to electricity prices and energy security.

Ember's analysis compares two potential scenarios: a **baseline** scenario, which reflects a current policy ambition trajectory, but assumes growth beyond many countries' NECP targets. And secondly the **ambitious** scenario, which uses 'high' industry forecasts. Both of these scenarios may be considered achievable, with the ambitious scenario requiring additional policy support.

In the ambitious scenario modelled by Ember, renewable generation in the CEE region increases by 31% (+84 TWh) by 2030 compared to the baseline, with gas and coal power falling by 7% (-5 TWh) and 15% (-8 TWh) respectively. With a larger volume of cheap wind and solar electricity in the mix, wholesale spot electricity prices decrease by 29%, with an average of 41 €/MWh compared to 57 €/MWh under the baseline scenario.



In this high renewables scenario, CEE's average power prices drop from some of the most expensive in the EU in 2022 to below average. This lower wholesale price would not only benefit business consumers and industry, but also households. Studies show that decreases in wholesale price driven by increased renewables far exceed additional system costs (including infrastructure investments, balancing or support scheme costs), and lead to lower consumer tariffs.

In fact, the cost of new wind or solar generation with storage in the region is already lower than existing coal and gas power. This trend is only expected to continue as carbon costs increase.

The analysis presented in the report uses Ember's in-house open power system model PyPSA-CEE to calculate a least-cost electricity generation mix across Europe, assessing the implications of different scenarios on price formation, emissions, flows, grid expansion needs and more. A detailed description of the model mechanics, assumptions and used datasets is provided in the Annex.

"A large part of the countries of Central and Eastern Europe have fallen asleep in the deployment of renewable energy. However, even historically fossil fuel reliant countries like Czechia are now starting to notice the benefits of the energy transition. But the removal of barriers to renewables must be completed as soon as possible: the preparation of a project, for example a wind turbine, must not take 10 or more years, but a year or two at most."

Stepan Chalupa
Chair of Czech Renewable Energy Chamber

"Slovakia should first of all focus on more ambitious RES targets. There is more potential in solar energy than is currently being developed. In addition, permitting processes are not flexible and fast enough, which hampers the whole process of renewables deployment."

Alžbeta Gavalcová
Junior Research Fellow at
Slovak Foreign Policy Association (SFPA)

Failing to keep up with Europe's energy transition will make the CEE region uncompetitive

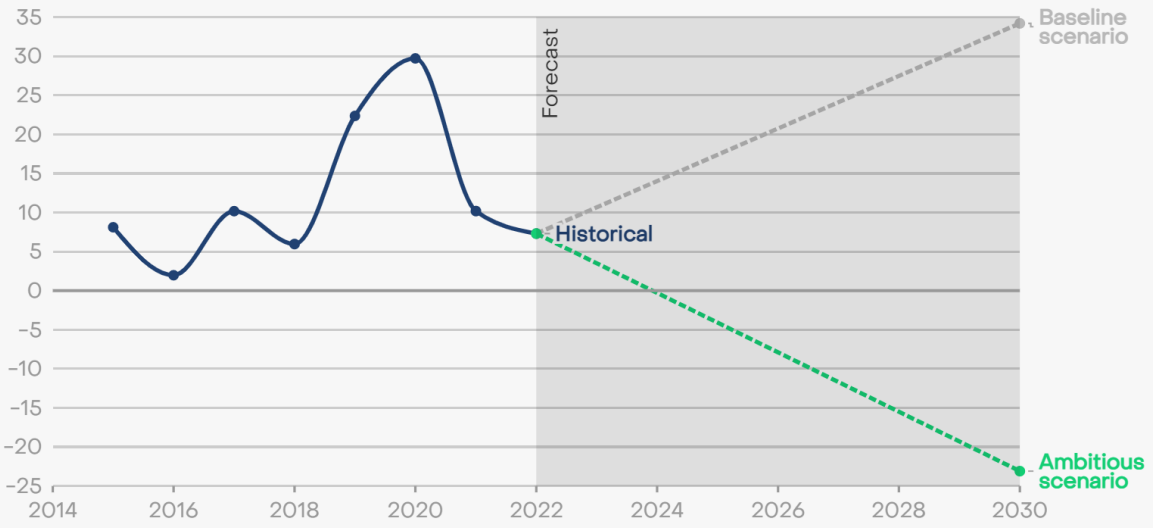
Russia's invasion of Ukraine was a painful reminder of the vulnerabilities of a fossil fuel based energy system, exposing multiple countries to political blackmail and economic pressure. CEE's response to the energy crisis has lacked drive to move away from the fundamental problem of fossil fuel reliance, with the only major announcement coming from Estonia which is now targeting 100% renewable power in 2030.

At the same time multiple western European governments have recognised the risks associated with gas and coal, and are increasing energy transition ambition in response to Russia's aggression. As a whole, the EU is now planning a rapid shift away from fossil fuels, and CEE countries will need to step up the pace of renewables deployment to avoid being left behind.

If CEE countries fail to accelerate wind and solar and stick to current unambitious plans, they will be forced to import 34 TWh of electricity in 2030, a five-fold increase from 2022. The faster and larger-scale planned deployment of cheap renewables in neighbouring countries would contribute to the diminishing competitiveness of CEE economies and higher costs of living if the region fails to keep pace.

Through more wind and solar expansion, the CEE region could turn into energy exporters

Net imports of electricity into CEE countries (TWh)



Source: Ember PyPSA-CEE model
2030 NECP = National Energy and Climate Plan targets, 2030 Baseline = latest national targets and low industry forecast extrapolation, 2030 Ambitious = national studies and high industry forecast extrapolation

Comparing renewables targets in European countries shows just how outdated the energy strategies in some CEE countries are. Hungary, Slovakia, Bulgaria, Czechia and Poland occupy the bottom five places in terms of national renewable electricity targets from the 2019 NECPs, aiming for around 20 percent renewable power in 2030. Even taking into account the latest political announcements, those country targets remain below 40%. By contrast, Germany, Denmark, the Netherlands, Portugal and Austria are all aiming for at least 80%.

The lack of green electricity in national power grids is quickly becoming a blocker for businesses, who are joining initiatives like RE100 (aiming to source 100% renewable electricity by 2050 at the latest) or looking to stabilise their operational costs through Power Purchase Agreements with renewable electricity providers. To keep attracting new investments, countries must provide cheap and stable electricity, and keep up with global climate policies to fulfil enterprise ESG benchmarks.

There is significant financial advantage to keeping pace with the EU's direction of travel on energy transition too. The high-ambition scenario modelled by Ember would put the CEE region in line with EU targets, opening up additional funding needed to implement the energy

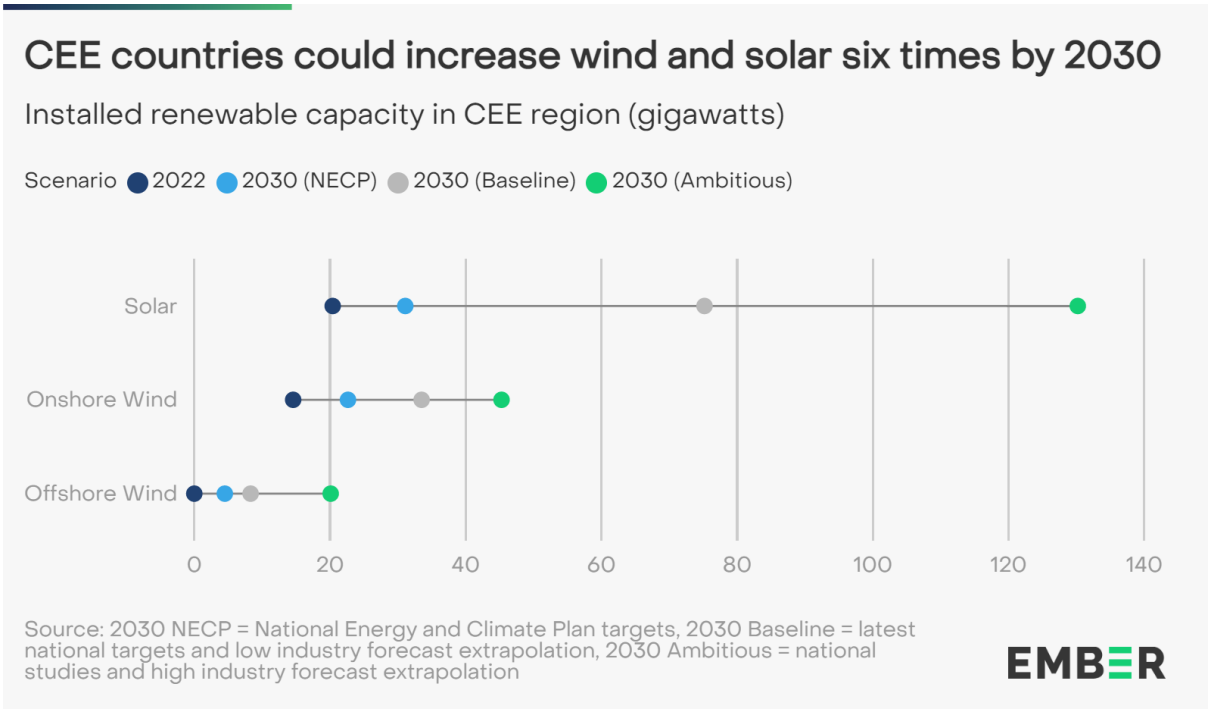
transition in CEE countries. Grants alone available for CEE countries under the Recovery and Resilience Facility amount to €71.6 billion. This can be topped up by €17 billion from the Just Transition Fund and at least €48 billion from the Modernization Fund. In total, this amounts to €137 billion, which is comparable to the investments needed for the complete climate neutrality transition of a leading industrial CEE economy like Czechia (€168 billion).

To unlock these funds, it is critical that strategic documents such as RRPs and NECPs contain ambitious wind and solar targets compatible with policies such as the Renewable Energy Directive target of 42.5% and the EU Climate Law.

CEE countries can deliver 200 GW of wind and solar by 2030

In 2022, CEE countries had a total of 14 GW wind and 20 GW solar capacity installed. This accounts for just 7% and 12% of EU totals respectively. Since the region spans a range of geographies and climates, there is scope for huge growth in renewables. The Baltic and Black Seas have high potential for offshore wind, and the central and southern regions are rich in solar resources.

Momentum is already building in the region. Last year, CEE wind and solar capacity grew by around 28%, above the EU-wide average of 15%. Across the region, countries are reaching new renewable records as wind and solar markets continue to grow. In SolarPower Europe's latest market outlook, Poland was ranked as 3rd biggest solar market in the EU. In 2022, all CEE countries with the exception of Bulgaria also saw the highest ever share of solar generation in their electricity mix. Hungary in particular is an example of the scale of growth that can be achieved. The country added almost 1 GW solar capacity last year, taking the total to 3 GW, up from just 300 MW in 2017. However, it is now facing significant grid capacity shortages. Solar is not the only technology setting records: 2022 also saw Croatia, Latvia, Poland and Romania reach record wind generation share, with Croatia the highest of any CEE country at 17%.



Solar capacity

In the baseline scenario, which reflects a current policy ambition trajectory, CEE solar capacity reaches 75 GW by 2030. This would already be close to quadruple the current capacity of 20 GW. But solar growth could realistically reach much higher heights. In the ambitious scenario, extrapolating from favourable industry forecasts from SolarPower Europe, solar capacity rises to 130 GW in CEE, with the largest percentage increases seen in Latvia, Croatia and Lithuania.

Onshore wind capacity

Onshore wind energy in CEE countries could also grow much faster than the baseline scenario given the correct policy conditions, potentially reaching 45 GW in 2030. In Czechia, industry ambition indicates potential for 1.6 GW, 50% more than the government target of 1 GW. In Hungary, at least 1.5 GW of onshore wind projects were halted by legal changes introduced in 2016; unlocking these alone would mean reaching five times the target stated in the National Energy and Climate Plan. In Poland, shifting the restrictive distancing rules to the agreed upon 500 metres (instead of 700 metres as introduced by the government in 2023) could add 5 GW to onshore wind capacity by 2030.

Wind and solar installed capacities under different scenarios								
Country	Wind (GW)				Solar (GW)			
	2022	2030			2022	2030		
		NECP	Baseline	Ambitious		NECP	Baseline	Ambitious
Bulgaria	0.7	0.95	2.7	5.7	1.2	3.2	8.5	8.5
Croatia	1.1	1.4	2.0	3.7	0.2	0.8	1.1	3.5
Czechia	0.3	1.0	1.0	1.6	2.3	4.0	5.2	12.5
Estonia	0.3	1.2	2.0	4.5	0.6	0.4	1.6	4.1
Hungary	0.3	0.3	0.3	1.5	3.1	6.5	8.4	13.6
Latvia	0.1	1.0	2.2	4.6	0.0	0.0	0.5	2.3
Lithuania	0.7	1.9	5.0	5.0	0.3	0.9	2.0	3.9
Poland	7.9	13.4	19.9	26.3	10.0	7.3	37.0	58.2
Romania	3.0	5.3	6.0	10.2	1.5	5.1	7.4	16.5
Slovakia	0.0	0.5	0.5	1.7	0.5	1.2	1.2	2.3
Slovenia	0.0	0.2	0.2	0.6	0.6	1.7	2.2	4.9

**AC capacity values are used throughout the report.*

Offshore wind capacity

Currently, CEE countries have no installed offshore wind capacity. The ambitious scenario sees this jump to 20 GW by 2030 compared to 8 GW in the baseline. With offshore wind facing less political opposition and the long-term potential in the region exceeding 100 GW, this technology could become a priority. Poland targets 5.9 GW offshore wind in the PEP2040 energy strategy, but could reach 7.5 GW if favourable policy and financing conditions allowed the acceleration of the 1.5 GW MFW Bałtyk 1 project. Estonia's ambition for 100% renewable electricity by 2030 will require a step up in their offshore wind plans, with up to 2.9 GW possible by 2030. Meanwhile in the Black Sea, Romania and Bulgaria are discussing a shared energy island that would reduce infrastructure costs and help to integrate green electricity into their national grids, with Romania alone potentially installing 3 GW of offshore wind by 2030.

Ambitious wind and solar buildout can triple the share of renewable electricity in some CEE countries

Share of renewables in electricity generation (%)

Source: Ember PyPSA-CEE model
Top 6 countries by electricity demand are shown. 2030 NECP = National Energy and Climate Plan targets, 2030 Baseline = latest national targets and low industry forecast extrapolation, 2030 Ambitious = national studies and high industry forecast extrapolation

In total, the CEE region could aim for 196 GW of wind and solar capacity by 2030, an almost six-fold increase from the 35 GW in 2022 and almost two times more than in the baseline scenario (117 GW). While this sounds like a big undertaking, the proposed numbers are still significantly smaller than the 360 GW of wind and solar targeted by the German government (239 GW increase from 2022), despite the fact that CEE countries in total have a similar population and three times the land area.

Following the ambitious scenario allows the CEE region to reach a 63% share of renewables in electricity generation in 2030, a significant increase compared to the 25% in 2022 and the 54% resulting from the baseline scenario.

In the EU as a whole, current national plans lead to a 64% renewable electricity share by 2030, with more progress made difficult by the low targets of some CEE governments. Increasing the CEE's ambition levels would result in a 70% RES share in the EU, making it possible to meet the REPowerEU target and putting the bloc on track to achieve a net-zero power system by 2040.

Aiming for more ambitious renewables growth is also realistic from a systems perspective, with examples of successfully balancing power systems with high shares of renewables already evident. Greece ran entirely on renewables for five hours in October 2022, the UK hit a similar milestone over 50 hours in Q4 2023, California achieved 100% clean power in April 2023, and South Australia ran on 100% wind and solar for over 10 days.

"Central and Eastern Europe already produces many components for wind turbines. They will benefit from the expansion of wind. They have great potential for more wind farms too. And more wind farms means cheaper electricity. So more wind is win-win-win for Central and Eastern Europe."

Giles Dickson
CEO of WindEurope

"Poland is already one of Europe's solar leaders, and we see similar potential across Central and Eastern Europe. Today and tomorrow, homegrown renewables are the basis of European energy security - system operators must prepare the grid accordingly. In an energy and climate crisis, we can't afford to waste a single ray of sunlight."

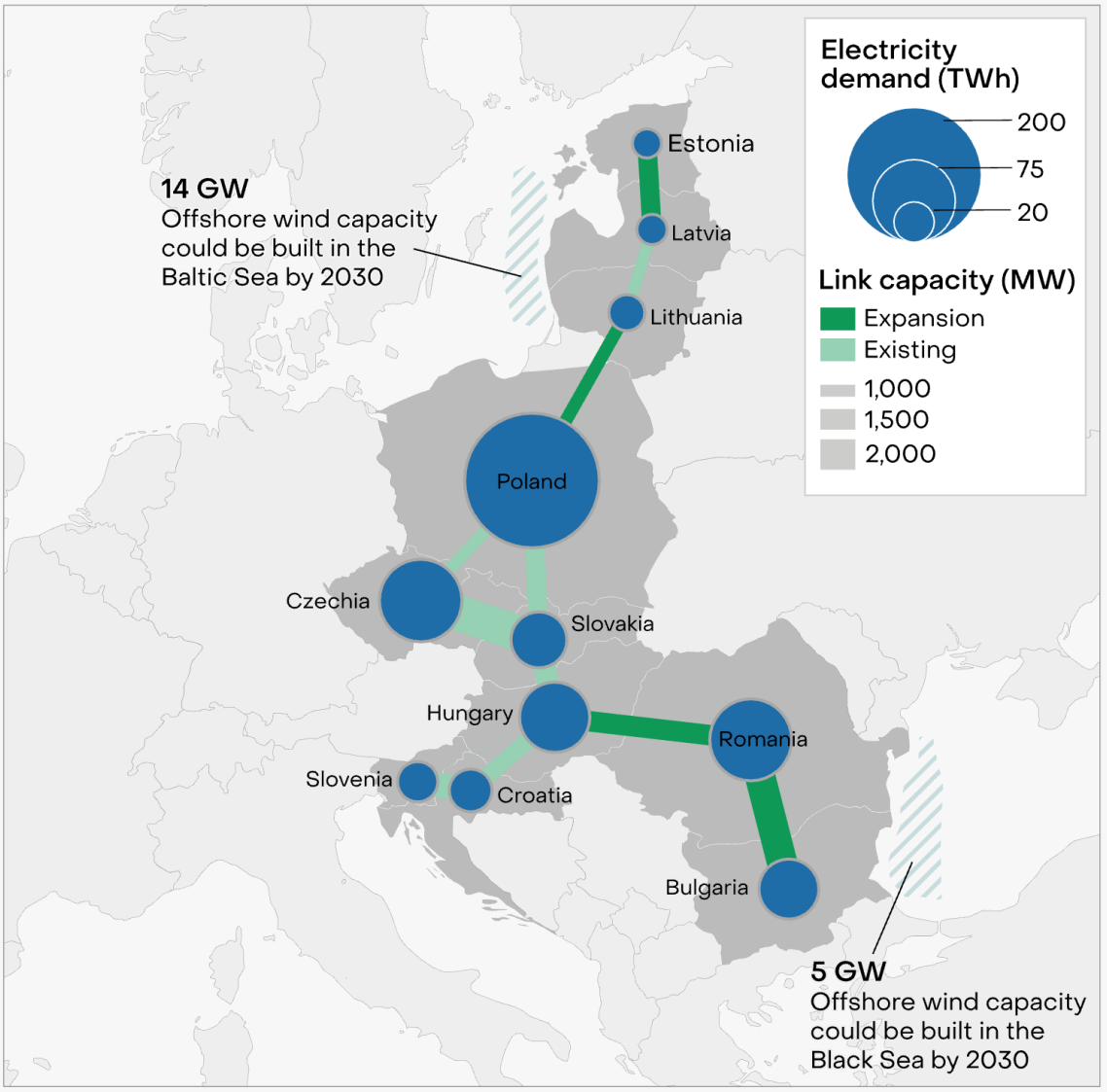
Walburga Hemetsberger
CEO of SolarPower Europe

Collaboration is necessary to unlock the region's full potential

The CEE countries vary significantly in terms of their renewables potential and the history of their energy systems. Perhaps the most obvious difference is sea access: some of the largest energy consumers, like Czechia or Hungary, are not able to access the advantages of offshore wind energy. On the other hand, countries such as Latvia and Estonia could host over 20 GW of offshore wind farms, generating at least 73 TWh of electricity per year. This would be three or four times higher than the expected 2030 electricity demand in both of those countries, allowing for exports to countries with higher demand. This means that the full potential of the region can only be unlocked by cross-country collaboration, with countries sharing the cheap green electricity, but also co-financing the necessary investments.

Regional collaboration can help tap into CEE's full wind and solar potential

Existing and planned interconnection capacities (lines) and 2030 electricity demand (circles) in the CEE region



Source: Ember, ENTSO-E TYNDP
Note: Link expansion includes projects that are scheduled to be commissioned by 2030 according to ENTSO-E TYNDP 2022

Collaboration is already underway

The idea of trans-national energy collaboration in the region is not new, with several projects already underway or proposed. These include the EL-WIND project co-developed by Estonia and Latvia, aiming to deliver 1 GW of offshore capacity; the 700 MW EstLink 3

interconnector; the 700 MW HarmonyLink HVDC connector; and the 500-1000 MW LitPol link co-developed by Poland and Lithuania. A shared Bulgaria-Romania energy island is also being discussed, with up to 3 GW of offshore wind capacity, and a 'Black-Sea Corridor' shared grid expansion project is already underway. Another energy island concept between Poland, Sweden and Lithuania was proposed, following the many examples being developed in Western Europe such as the Bornholm Energy Island on the Baltic Sea. A precedent for cross-border renewables investments has also been made recently, with Luxembourg and Finland planning a cross-border tender for renewable energy. Similar tenders could help co-finance investments in countries where the wind or solar potential exceeds the host country's financing capabilities.

Expanding connection

More interconnections can improve the integration of offshore wind electricity across the region, and the transfer of clean power into high demand areas. At the moment, interconnections within the CEE region constitute only 13% of the EU's internal interconnection capacity. Our modelling shows that additional interconnection capacity in the region further reduces power prices and improves the integration of wind and solar by lowering energy curtailment

There is funding available for more ambitious grid expansion too. The cross-border grid projects can benefit from EU funding under the Connecting Europe Facility, with a €5.8 billion budget between 2021 and 2027, as well as funding from the European Investment Bank. Financial support for grid projects is also available under the Modernisation Fund (25% of the €14 billion budget) or the Recovery and Resilience Fund (between €5.1 and €6.8 billion).

Detailed country studies have shown that modernising all grid levels, while costly, still has a positive impact on consumer tariffs thanks to the lowered wholesale power prices. However, there are some challenges to keep in mind as projects take shape. The effective use of interconnectors is only possible if they do not cause additional strain on national grids. This can be achieved, for example, by coupling with phase shifting transformers or implementing via HVDC lines. Country transmission grids need to be strengthened as well, and distribution grid bottlenecks unlocked to allow the full integration of renewables.

"The recent reluctance of several CEE countries to adopt more ambitious EU renewable energy goals for 2030 could turn into a threat for the region's energy security and competitiveness. This report reveals that there is a substantial commercial interest in developing renewable energy capacity in the CEE and installing it is achievable. EU instruments provide generous funding for the energy transition in the region, in addition to national budgets and potential private investment. The CEE countries should use the drafting of Recovery And Resilience Plans and the revision of the National Energy And Climate Plans due next month to signal their interest in seizing this opportunity."

Genady Kondarev
Senior Associate For Central And
Eastern Europe, E3G

Conclusion

Unlocking wind and solar brings multiple benefits

Fully accessing the renewables potential is only achievable through collaboration, both within the region and with the whole EU

There is no doubt that the EU as a whole and the majority of its Member States are accelerating their energy transition in response to multiple crises: Russia's invasion of Ukraine, the global gas supply shortage, the COVID-19 pandemic. Across Europe, countries are now recognizing that domestic wind and solar electricity provides greater security than imported coal and gas.

With their history and close proximity to Russia, CEE countries need to hop on the pan-European clean power train. Failing to do so will have dire economic and security consequences. There is also no compelling reason not to. Multiple studies, including this one, show that more wind and solar electricity leads to lower power prices, reduced import dependency, but also job creation and the stimulation of local economies. Several funding programs are available to cover all parts of the energy transition, including the related grid investments. The upcoming revisions of NECPs and RRPs are the perfect opportunities, and perhaps the last ones, for CEE countries to develop ambitious renewables targets.

Key recommendations

Unlocking the high levels of wind and solar capacity modelled in this report is realistic with current technologies. Coordinated and ambitious actions on the part of governments and policymakers, grid operators and local administrations are what will make this pathway possible.

Governments and policymakers

1. Update NECP targets to represent industry forecasts and economic potential.
2. Include ambitious wind and solar development plans and grid expansions projects in the RePowerEU related chapter of RRPs.
3. Eliminate national policy barriers to wind and solar deployment, such as the onshore wind distancing rules in Poland and Hungary.
4. Incentivize storage and power system flexibility to allow for the better integration of wind and solar with transmission and distribution grids.

Grid operators

1. Develop a cross-border grid expansion project from the Baltic Sea to the Black Sea that would open up the offshore wind potential of the CEE region. Build on projects that are already underway or being discussed.
2. Plan for the expansion of interconnectors beyond the needs indicated by ENTSO-E for 2030, potentially utilising the 'Overriding public interest' rule for renewables and related grid infrastructure introduced by the EU Council in late 2022.
3. Include accelerated heat pump and EV deployment rates in line with latest industry forecasts in TSO demand projections.

Local administration

1. Increase administrative capacity to ensure effective usage of available EU funding for the energy transition and grid investments.
2. Lower permitting times for wind and solar investments to meet the Renewable Energy Directive and emergency regulation requirements of 18-24 months.
3. Increase data transparency in the areas of permitting by providing a list of projects at different stages of the development process.

Annex

Modelling the European power market

PyPSA-CEE model overview

PyPSA-CEE is Ember's EU-wide open power system model developed using the PyPSA framework, a Python-based 'open source toolbox for simulating and optimising modern power systems'. The results and input data are publicly available under the MIT licence, allowing for all analysts to replicate our results or build their own scenarios for Europe's future energy system

The model runs at hourly resolution and ensures the correct balancing of the EU-wide electricity system. Hourly demand and climate generation profiles (wind, solar and hydro) are taken from ENTSO-E's Pan-European Climate Database (PECD) which provides data for all years between 1980 and 2019. For this model, data from the worst-case climate year 2008 is used. The demand profile is taken from ENTSO-E's Distributed Energy pathway, a scenario with a decentralised focus on renewables which achieves at least a 55 % emission reduction in 2030. The model is optimised according to dispatch only, with no possibility for capacity expansion given the short 2030 time frame and focus on real-life delivery of proposed projects (although see notes on grid expansion below).

The model consists of 29 country nodes representing all EU countries except Luxembourg, Malta and Cyprus, as well as the United Kingdom, Norway, Switzerland, Turkey and Russia. Technology capacities for coal, gas, oil, biomass, nuclear and hydro (pumped storage, reservoir and run-of-river) are derived per country according to latest policy announcements, taking into account nuclear expansion/closures, coal phaseouts and future gas capacity plans. Renewable capacities differ according to the scenario as described below.

Coal and gas capacity is provided at unit level (developed from Global Energy Monitor's power plant databases) and split into power-only and combined heat and power (CHP) units. Future gas CHP units built between 2023 and 2030 are assumed to replace the equivalent capacity of coal CHP units per country. A phase out of coal capacity is applied using linear extrapolation to the specified phase out date for countries with official phaseout plans. This results in a phase out of around 13% coal CHP capacity, which is assumed to be covered by increased energy efficiency according to the latest Energy Efficiency Directive. Another 17% of gas CHPs are converted to renewable CHPs, in line with the agreed amendments to the Renewable Energy Directive.

Nuclear units are set to a minimum 40% load factor. CHP units are set to run with a semi-fixed generation profile related to historic heat demand.

The model was calibrated using installed generation capacity and ENTSO-E demand data from 2021. Model results were compared to ENTSO-E generation data by country by technology to ensure the power grid simulation produces robust results.

All model input files as well as the Python code are available on Github.

Scenario definitions

For the 2030 **baseline** scenario (BASE), wind and solar capacities are taken as the highest value of the following sources: latest country target announcements; national energy and climate plans (NECPs) or extrapolated forecasts from industry (SolarPower Europe's low scenario in the case of solar or WindEurope's central scenario in the case of wind). This approach was chosen because the existing capacity targets in some countries are significantly outdated and the base industry forecasts give a better representation of the status quo given the rapid on-the-ground deployment of solar energy. However, this means that the baseline scenario is already much more ambitious than the existing NECPs.

The **ambitious** scenario (AMB) uses 'high' industry forecasts, showing the benefits of accelerated wind and solar deployment, whilst keeping other technology capacities the same. Solar capacities are Ember's 2030 forecast based on SolarPower Europe's 'high' scenario for the years 2023-2026. The exception to this approach is Bulgaria, which has recently announced a 30-year energy strategy document with a target of 8.5 GW solar in 2030, beyond our forecast, and Czechia, where national estimates provide a higher number than indicated by our extrapolation (12.5 GW against 11.6 GW). Wind capacities in the ambitious scenario were gathered from a variety of sources including country level studies and academic research (full table below). The ambitious capacities should be understood as

realistic with current technologies and conditions if additional policy support was introduced to enable, for example, shorter permitting times and better grid access.

Estimating ambitious 2030 wind capacity

The following table provides the sources and calculations used to estimate onshore and offshore wind capacity in 2030 in the ambitious scenario.

Country	Onshore wind (MW)	Offshore wind (MW)
Bulgaria	3907	1800
Croatia	3000 (extrapolated from WindEurope)	715 * (technical potential 4 GW fixed)
Czechia	1600	0
Estonia	1630 - 1300 MW in 2028, extrapolated to 2030	2900
Hungary	1500 - in 2010, 410 MW tender cancelled + applications for 1100 MW	0
Latvia	2000	2592 * (technical potential 14.5 GW)
Lithuania	3600	1400
Poland	18800	7463 (assumes 1560 MW MFW Bałtyk I comes online by 2030 in addition to 5900 MW baseline)
Romania	7002	3200 (assumes 5 GW total between Romania and Bulgaria)
Slovakia	1680 - SAPI use 1% of 168 GW technical potential for ambitious 2030 scenario	0
Slovenia	560	0

** Based on Poland's energy strategy and development pipeline, total offshore wind capacity will reach 18% of potential by 2030. Capacity for countries marked with an asterisk are taken as 18% of their own total offshore wind potential, aligned with the pace of Polish offshore wind deployment.*

Price assumptions

2030 price forecasts were based on the latest available futures contracts, except for lignite costs that were sourced from IEEFA and adapted according to the unit's efficiency.

Commodity	2030 Value	Source
Hard coal	14.16 €/MWht	API2
Lignite	22 €/MWhe @ 35% efficiency	IEEFA
Gas	44.57 €/MWht	TTF
Oil	35.9 €/MWht	Oil Brent
CO2	108.4 €/t	EEX

Modelling grid expansion

Country nodes represented in the model are connected by interconnectors. The existing capacity for each link is based on 2021 net-transfer capacities - with a total of 29.6 GW within the CEE region. For 2030 baseline and ambitious scenarios, the existing capacity is increased taking into account projects already in development according to ENTSO-E's TYNDP 2020 and 2022 (2025 reference grid) - adding 9 GW.

An additional sensitivity scenario was implemented to assess the impacts of more interconnection on the region's power system. This assumed the implementation of projects outlined in the ENTSO-E Needs study for 2030 - adding 4.2 GW (two bidirectional ~1 GW projects). On top of those projects, link capacities were allowed to expand through cost-optimization (up to 1.5x the starting capacity to accommodate for the short 2030 timeframe), adding another 5.5 GW in interconnection capacity by 2030.

Border	Existing projects (GW)		New projects (GW)		
	NTC 2021	In construction	ENTSOE Needs 2030	Ember 2030	ENTSOE Needs 2040
Bulgaria-Romania	1.8	0.6	1	1	1.5
Romania-Bulgaria	1.5	0.6	1	1	1.5
Czechia-Poland	0.9	0	0	0.5	1
Poland-Czechia	2.3	0	0	1.2	1
Czechia-Slovakia	2.8	0	0	0	0.5
Slovakia-Czechia	1.1	0	0	0.5	0.5
Poland-Slovakia	1.5	0	0	0	1.5

Slovakia-Poland	0.6	0	0	0.3	1.5
Estonia-Latvia	0.9	0.6	0	0	0.5
Latvia-Estonia	0.6	0.6	0	0	0.5
Latvia-Lithuania	1.3	0	0	0.2	0
Lithuania-Latvia	0.9	0	0	0	0
Lithuania-Poland	0.5	0.5	0	0.5	0.7
Poland-Lithuania	0.5	0.5	0	0	0.7
Croatia-Slovenia	1.9	0	0	0	2
Slovenia-Croatia	1.5	0.15	0	0	2
Hungary-Romania	1	0.6	1.1	1.5	0
Romania-Hungary	0.8	0.3	1.1	1.1	0
Hungary-Slovenia	0	1.2*	0	0	1
Slovenia-Hungary	0	1.2*	0	0	1
Hungary-Slovakia	0.9	0.8*	0	0.9	1.5
Slovakia-Hungary	3.3	1.3*	0	0	1.5
Croatia-Hungary	1.3	0	0	0	0
Hungary-Croatia	1.7	0	0	0	0

**The HU-SL-HR and the HU-SK projects were commissioned between 2021 and 2023 so were not fully included in the 2021 NTC value but rather added as part of the 2025 TYNDP reference grid (hence they are marked as 'In construction')*

The investment cost assumptions for link expansion were based on existing TYNDP projects (e.g. the new 400 kV CZ-SK line or the HU-RO line) or the announced costs of undersea projects such as EstLink 3 and HarmonyLink and varied depending on the length of the connector and the type (land or subsea). To incentivize link expansion and based on the HarmonyLink financing structure, up to 72.5% of capex was assumed to be covered by the Connecting Europe Facility. The cost of the additional 5.5. GW expansion in the Ember sensitivity scenario is €4.9 billion with €1.4 billion funded from national sources and the rest coming from the CEF.

The results show the need for significantly expanding transit lines - between Poland, Czechia and Slovakia, as well as between Hungary, Romania and Bulgaria - allowing for better North-South electricity transits. The most congested link in the region is the one between Lithuania and Poland, requiring significant expansion and providing yet another argument for the quicker implementation of the HarmonyLink project, as well as the swift delivery of all phases of the LitPol expansion project. The additional 9.8 GW of interconnection capacity (one-way) in the Ember sensitivity scenario reduces CEE average power prices by a further

3% compared to the ambitious scenario, while also lowering wind and solar curtailment by 13%.

It's important to note that the proposed acceleration of wind and solar requires grid expansion on all levels - from distribution, through transmission, to interconnection. The lack of distribution grid capacity is already slowing down solar farms in several European countries. It is estimated that 15 GW of renewable energy projects were declined grid connection permits in 2021 alone due to the poor condition of the Polish distribution grid. The Hungarian grid operator, MAVIR, announced last May that there was no available grid capacity for weather-dependent power plants, with no new connection requests accepted until at least May 2023. However, MAVIR has recently announced they will spend more than €1 billion in the next four years to modernise and expand the grid and believe Hungary can still reach its 2030 energy targets earlier than planned. In Czechia, grid bottlenecks are delaying connections for rooftop solar and lack of a transparent system for investors to identify where connections are available means they often over-submit applications for large-scale projects, leading operators to refuse smaller connections.

These grid challenges were to a significant extent caused by the lack of adequate planning - countries setting extremely low renewables targets that were then used as a basis for not extensive enough grid expansion planning despite the on-the-ground trends and industry forecasts. Ironically, in some cases, such as the Polish TSO's grid expansion plan, the operator assumed a 50% renewables electricity by 2030 compared to the official government target of 32% set just a year earlier. This inconsistency in energy system planning makes it difficult to realise and finance investments as complex as grids and needs to be addressed on a European and national level - starting with up-to-date and ambitious wind and solar targets in the NECPs, within the TYNDP process and in national grid expansion plans.

Supporting Materials

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