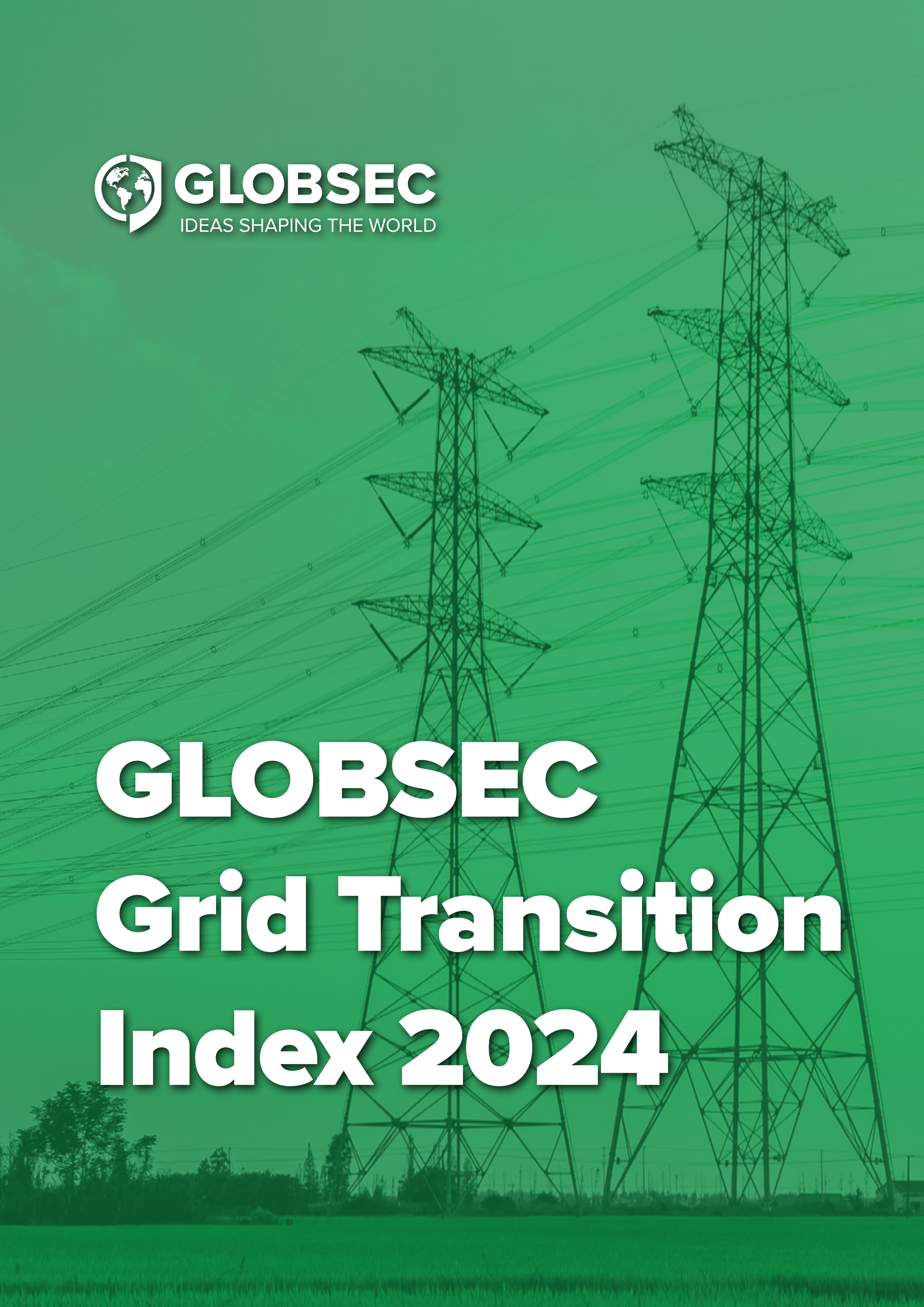


IDEAS SHAPING THE WORLD

GLOBSEC Grid Transition Index 2024

Author:

Ján Mykhalchyk Hradický, GLOBSEC External Research Fellow

Assistance provided by: **Katarína Strauszová, Olivia Strapeková,** GLOBSEC

We thank the members of the **GLOBSEC Energy Advisory Committee,** who provided essential input and feedback during the write-up of the report. The report as such, however, is the responsibility of the author and does not express the official opinions of the Committee members or the institutions they represent.

Members of the GLOBSEC Energy Advisory Committee:

Zsofia Beck, Managing Director and Partner, Boston Consulting Group

Andrei Covatariu, Senior Research Associate at Energy Policy Group

Naďa Hartmann, Chair of the Board and CEO, ESCO Slovensko

Ákos Lósz, former Senior Research Associate, Columbia University's Center on Global Energy Policy

Jan Rosenow, Principal and Director of European Programmes, Regulatory Assistance Project

In memory of Adam Horehaj, a dear friend to all of us.

Table of Contents

Executive Summary

Green transition requires grid transition. Transformation of energy systems to achieve a more sustainable future requires integrating large volumes of intermittent renewable energy. In addition, the decarbonization will require electrification of sectors traditionally powered by fossil fuels. This electrification will place significant pressure on electricity grids that will have to transmit higher amounts of electricity and accommodate new consumption patterns. The expectations placed on electricity grids are hard to overstate.

However, the current state of some electricity grids casts doubts on their ability to support such an ambitious transition. Even today, the inability to connect new customers, service interruptions, and struggles to integrate modest levels of renewable energy suggest that many grids may not be up to the task, posing a significant risk to the broader goal of a green transition.

35 countries covered

Until now, there has been no quantitative assessment of how prepared European grids are for this critical shift. Grid transition is a complex and multifaceted challenge involving numerous attributes of each energy system and the intricate relationships between them. Due to methodological challenges, a complex comparative study of grid transition has not been attempted.

30 indicators used

To fill this gap, GLOBSEC presents its first-ever Grid Transition Index. This Index evaluates the readiness of 35 European countries for the grid transition, assessing their performance across three dimensions: the current state of grid infrastructure and economic fundamentals, the grid state in 2030, and the adoption of enabling technologies that are critical for a successful grid transition.

3,500,000+ data points analyzed

Our findings reveal significant disparities in grid transition readiness, even among neighbouring countries. While Western European countries generally perform better, notable exceptions include the Netherlands, Germany, and Ireland. Conversely, several Central and Eastern European countries are outperforming their Western counterparts, challenging common perceptions and highlighting the importance of responsible energy policies to a sustainable and reliable energy future (Map 1).

Current Grid Challenges and Electricity Markets

\+

Grid Challenges in 2030

\+

Opportunities

=

GLOBSEC Grid Transition Index

Even though notable progress was made, electricity generation from fossil fuels is still widespread across Europe. On average, more than 40% of electricity is produced from fossil fuels in 35 European countries, a significant majority of which will have to be phased out within the next decade(s), increasing stress on grids.

The Index highlights differences in the expected adoption of renewables and new grid technologies. The widening gap in renewable deployment could magnify differences in electricity prices, industrial competitiveness, and ESG performance across Europe. Regarding new technologies, all EU countries expect some integration of grid batteries by 2030, but the scale varies widely. Even more heterogeneous is the adoption of demand response – seven EU countries are not planning for any demand response capabilities in 2030. Low adoption of new technologies may necessitate more physical infrastructure and increase system costs.

Grid transition remains neglected in policymaking. Although quantifying the political salience of grid transition is difficult, national Recovery and Resilience Plans suggest that only a few EU countries fully reflect grids' importance. What is more, even some of the countries facing low levels of readiness did not use the potential of Recovery and Resilience Funds to improve their grids and adopt necessary reforms.

To successfully navigate the complexities of grid transition, policies must be customized to the unique circumstances of each country. The results of the Index underscore the need for tailored solutions. While general strategies like streamlined permitting and enhanced flexibility are applicable everywhere, others must be adapted to national contexts. For example, renewable subsidies may be inefficient in regions with congested connection queues and investment gaps in grid infrastructure. Instead, focusing on policies that improve grid infrastructure to remove bottlenecks may be more cost-effective.

Significant investment in grid infrastructure is needed, and the source of financing is crucial. Financing should not burden electricity consumers, as this could hinder the energy transition by driving up electricity costs. Apart from financial subsidies, the policymakers should enable grid transition by accelerating permitting processes for grids akin to those used for renewable energy development. Incorporating principles such as “go-to zones” and one-stop shops can help grid development keep pace with renewable energy deployment.

Map 1: Results of Grid Transition Index 2024

Source: GLOBSEC, mapchart.net

Introduction: Immense Grid Ambitions

On the 21st of June 2024, the Western Balkans faced an intense heatwave, a stark reminder of the growing impact of global warming. The heat caused a spike in electricity consumption as people increased their use of air-conditioning. At 12:09 PM, a seemingly minor incident occurred near Podgorica, the capital of Montenegro. A transmission line tripped due to a short circuit and caused a diversion of electricity flows to alternative routes.

What initially appeared to be a manageable disruption soon escalated. Just thirteen minutes later, at 12:22 PM, another transmission line, this time near the Albanian city of Korçë, some 250 kilometres south, experienced a similar fate. The combination of these two events, while insignificant in isolation, triggered a cascade effect that would plunge almost ten million people into a blackout. Interconnected transmission systems, usually pillars of stability and economic efficiency, instead facilitated the rapid spread of the blackout, affecting Albania, Montenegro, Bosnia and Herzegovina, and a significant part of Croatia.

Within three hours, Transmission System Operators (TSOs) managed to restore electricity flows, but the incident left an indelible mark. Such events highlight the fragility of electricity grids and remind us of the total reliance people have on electricity. Blackouts, beyond their immediate inconvenience, pose severe risks to human lives in health facilities and inflict substantial economic losses, especially in industries that rely on precision and continuity.

The occurrence of transmission systems failing during extreme weather is particularly concerning, given the increasing importance of grids in the coming years. European grids currently face challenges such as infrastructure gaps, lengthy permitting processes, growing cybersecurity risks, and the need to enhance resilience in a world affected by climate change. Simultaneously, the expectations placed on European grids are exceptionally high.

Addressing climate change necessitates the electrification of energy usage, shifting from traditional fossil fuels to low-carbon electricity. This shift is detailed in the annual grid development forecasts submitted by TSOs. To meet climate targets, electricity consumption needs to nearly triple by 2030, requiring grids to handle this significant increase (Figure 1). Even if these ambitious targets are not fully met, achieving even half of the forecasted growth will be highly challenging.

Intermittent renewables will replace existing energy sources. Traditional fossil fuel generators are becoming increasingly uncompetitive due to carbon costs that reflect their negative externalities. Consequently, new renewable energy sources will not only need to meet rising demand but also replace decommissioned fossil fuel capacities. This presents a significant challenge for grid operators. In addition to the inherent intermittency of renewable sources, new renewable generators may be situated in different locations than the fossil generators they replace, necessitating the construction of new infrastructure or the upgrading of existing infrastructure.

Figure 1: Expected growth of electricity demand (EU)

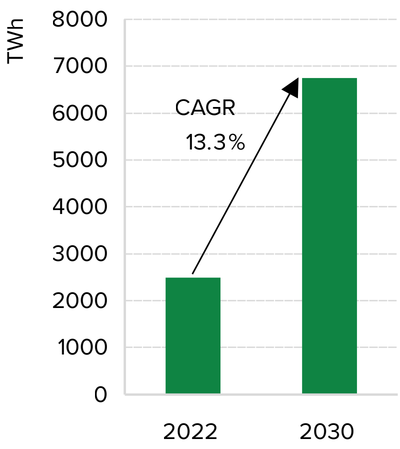


Figure 2: Expected growth of solar capacity in the EU

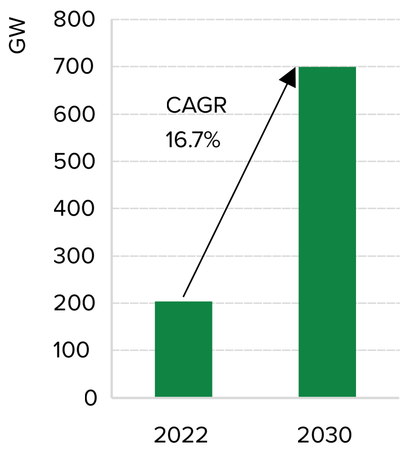
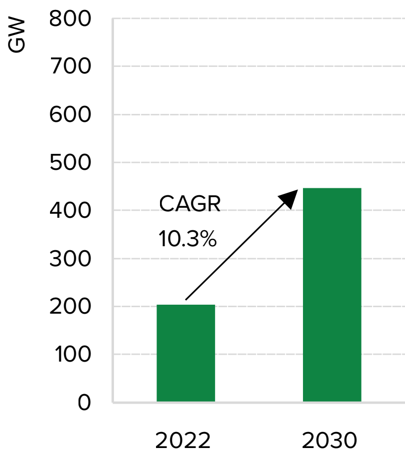


Figure 3: Expected growth of wind capacity in the EU



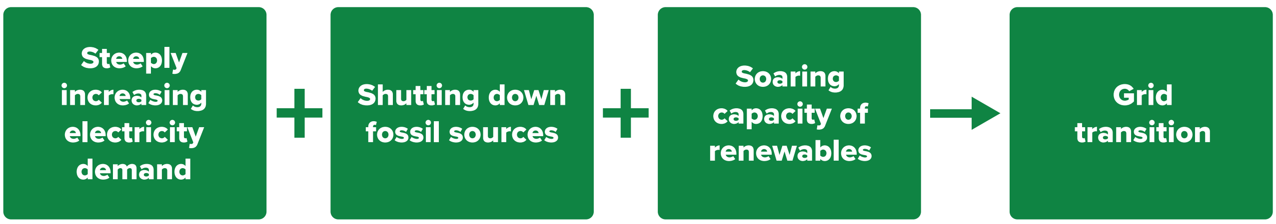
Source: ACER, Eurostat

The rapid increase in generation from intermittent renewables introduces a unique set of challenges. According to TSOs, solar capacity will need to expand by 250% and wind capacity by 150% by 2030 (Figures 2 and 3). Unlike traditional fossil fuel generators, renewable resources cannot provide baseload energy and cannot be easily ramped up or down. Although the number of battery storage systems paired with renewables has surged in recent years, offering promising developments, intermittent renewables still pose a significant challenge compared to traditional power sources.

Addressing these three external challenges requires a comprehensive *grid transition.* Accomplishing each of these steps individually is difficult, but achieving them simultaneously demands a profound transformation in the entire grid ecosystem. This shift involves not only TSOs but also Distribution System Operators (DSOs), state institutions, consumers, and generators. In this report, "grid transition" refers to this essential and broad change.

In addition to the ambitious goals they must meet, grid operators in developed power markets are grappling with several significant challenges, such as:

1. **Protracted Permitting Processes:** Developing new infrastructure often conflicts with slow permitting procedures and public opposition. In Europe, for example, constructing new overhead transmission lines typically takes about ten years (IEA, 2023a), posing substantial obstacles to further electrification efforts and integration of renewables.
2. **Corporate Inertia:** Grid operators face the challenge of accommodating a steep increase in electricity consumption following years of stagnation. Rigid corporate structures and outdated regulatory frameworks may struggle to adapt, creating obstacles to motivating grid operators to invest in grid modernization.
3. **Ageing Infrastructure:** In addition to the need for expansion and modernization to handle growing demand, grids must also address the issue of ageing infrastructure. Across Europe, approximately 50% of existing infrastructure will require replacement within the next one or two decades (IEA, 2023b: 27).



Literature Review

There is broad consensus on the critical role of grid transition in achieving the green transition (IPCC, 2022: 650; IEA, 2023b). According to the IEA (2023b), meeting national climate targets will require more than doubling the global grid length by 2050. Without this expansion, grid delays will hinder renewable energy integration and increase reliance on fossil fuels. Beyond extending grid connections, increasing grid flexibility through methods like energy storage, demand response, and flexible generation is essential (IPCC, 2022: 650-657).

The grid transition will come at a high cost. The IPCC highlights the substantial integration costs of renewable energy, which necessitate significant grid investments (IPCC, 2022: 632). The European Commission estimates that the EU alone will require €584 billion in grid investments by 2030 (EC, 2023: 2). Grids are also central to the Future of European Competitiveness report (Draghi, 2024: 14-15).

The pace of grid transition varies significantly across EU countries (de la Esperanza Mata Pérez, Scholten, Smith Stegen, 2019), reflecting differences in geopolitical, geographical, and political factors. These disparities are evident in national renewable energy policies and targets (Cremona, Rosslowe, 2024), as well as the differing conditions of electricity grids (de la Esperanza Mata Pérez, Scholten, Smith Stegen, 2019: 4).

There is no ranking evaluating the states of grid transition from a comparative perspective. There are a number of rankings studying overall energy performance, such as the Energy Transition Index by the World Economic Forum and Accenture (2023) and the World Energy Trilemma Framework developed by the World Energy Council (2022), but these also suffer from a number of shortcomings. Firstly, their high levels of abstraction make it challenging to identify specific policy recommendations tailored to individual countries. Secondly, as they aim for global comparability, their indices rely on broad and easily accessible data, which may not adequately capture the nuances of developed economies, particularly those in Europe. Thirdly, their untransparent methodologies worsen the replicability of findings and make it harder to identify the necessary policy actions.

Some analyses focus specifically on grids; however, they concentrate solely on specific aspects. For instance, SP Group (2022) studies smart characteristics of grids at the level of individual utilities, while other studies offer comprehensive and well-crafted policy proposals without providing rankings for individual countries (IEA, 2023b). Recognizing these limitations, there is a clear need for a novel analysis of grids from a comparative perspective.

Box 1: Recent Examples of Prominent Media Addressing Grid Bottlenecks

Financial Times, 2023: How a lack of power lines will delay the age of renewables

Economist, 2023: Can Europe's power grid cope with the green transition?

Wall Street Journal, 2024: The Coming Electricity Crisis: Artificial-intelligence data centers and climate rules are pushing the power grid to what could become a breaking point.

Bloomberg, 2023: A Giant Grid Bottleneck Is Threatening Climate Goals

Methodology: What is the Grid Transition Index?

The GLOBSEC Grid Transition Index assesses and ranks 35 European countries based on the likelihood of success of their grid transition. The key research question is: Which countries have grids most ready for grid transition, and which need to increase their efforts? The index is composite, consisting of thirty indicators organized across three areas.

- **Current Challenges and Electricity Markets (50 points).** Include the most recent data on the performance of grids (for example, losses, ability to predict load, load stability, and production of electricity from fossil fuels) and electricity market data (for example, day-ahead prices, imbalance volume, and imbalance prices).
- **Challenges in 2030 (25 points).** Using national strategic documents (National Energy Climate Plans and Resource Adequacy Assessments), the expected state of electricity grids in 2030 is evaluated in terms of challenges and risks.
- **Opportunities (25 points).** A number of readily available technologies improve the prospects of grid transition. Their current uptake is a positive signal for future grid transition.

An overview of indicators across different areas is enclosed on the following page. Detailed information with the data source, its year, and a justification is described in Annex 1.

The Index covers 27 EU countries and eight non-EU countries. The Index primarily focuses on EU countries as these are relatively homogenous in terms of their high ambitions and decarbonization policies (EU ETS). In addition, three non-EU Western European countries (Norway, Switzerland, United Kingdom) and five Western Balkan countries (Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Serbia) are added as well to offer a more comprehensive comparative perspective. The ambition for next year's Index is also to include Ukraine, Moldova, and Kosovo. Currently, these countries are not analysed due to data unavailability.

Scoring is based on the relative position of the countries. Therefore, a country with the best results for an indicator will get a full score, and the country with the worst result will receive zero points. Limited exceptions apply to this rule, as discussed in Annex 2. Other countries will be scored based on their relative position towards the best and the worst case within the EU.

Countries are categorized into four levels of preparedness based on their scores: highly prepared, moderately prepared, partially prepared, and not prepared. These categories reflect the relative standings of countries. While the decision on where to draw the boundaries between levels of preparedness is somewhat arbitrary, these borders were established to ensure that the difference between the highest-scoring country in a lower category and the lowest-scoring country in a higher category is at least one full point.

The Grid Transition Index is a snapshot of the situation. To track trends in grid transition across countries, the GTI will be updated annually to capture the evolving realities of European grids. Under the current methodology, over 90% of the indicators can be updated with new data each year.

The GTI will be expanded with new indicators for the next year's edition. For example, this would include energy-sitting policies (Enterline and Valainis, 2024). Ideas for new indicators, ideally including a data source, should be addressed to the author.

Table 1: Overview of the indicators and areas; detailed description enclosed in Annex 1

	Indicator	Higher value of indicator =	Scoring normalization	Scoring	Data year
Current Challenges and Electricity Markets	1. Electricity generation from coal (TWh)	lower score	Electricity consumption (2022)	10	2022
	2. Electricity generation from oil (TWh)	lower score	Electricity consumption (2022)		2022
	3. Electricity generation from gas (TWh)	lower score	Electricity consumption (2022)	4	2022
	4. Absolute imbalance volume (MWh)	lower score	Electricity consumption (2022)	5	2023
	5. Load forecast accuracy (%)	higher score	Average actual load (MW)	5	2023
	6. System Average Interruption Frequency Index (SAIFI)	lower score	-	3	2019
	7. Transmission losses (%)	lower score	-	3	2022
	8. Distribution losses (%)	lower score	-		2022
	9. Load standard deviation (MW)	lower score	Average actual load (MW)	2	2023
	10. Peak load (MW)	lower score	Average actual load (MW)	2	2023
	11. Day-ahead price volatility	lower score	-	6	2023
	12. Negative day-ahead prices (%)	lower score	-	6	2023
	13. Average imbalance price (€)	lower score	-	4	2023
Challenges in 2030	14. Growth of intermittent renewable capacity (MW)	lower score	Electricity consumption (2022)	7	2030
	15. Growth of intermittent renewable generation (TWh)	lower score	Electricity consumption (2022)	3	2030
	16. Growth of demand (TWh)	lower score	Electricity consumption (2022)	3	2030
	17. Capacity of batteries (MW)	higher score	Electricity consumption (2030)	3	2030
	18. Capacity of demand response (MW)	higher score	Electricity consumption (2030)	1	2030
	19. Reservoir and pondage hydro (MW)	higher score	Electricity consumption (2030)	3	2030
	20. Capacity of pumped hydro (MW)	higher score	Electricity consumption (2030)	3	2030
	21. Loss Of Load Expectation in 2030 (h/year)	lower score	-	2	2030
Opportunities	22. Generation of intermittent renewables today (TWh)	higher score	Electricity consumption (2022)	10	2022
	23. Cross-border transmission capacity (MW)	higher score	Average actual load (MW)	3	2023
	24. Electricity net import (MWh)	lower score	Electricity consumption (2022)	2	2022
	25. Pumped hydro today (MWh)	higher score	Electricity consumption (2022)	3	2022
	26. Consumers with smart meters (%)	higher score	-	3	2022
	27. Electricity consumption for space and water heating (%)	higher score	Space and water heating (2022)	1	2022
	28. Funding in RRFs earmarked for the grid investments	higher score	-	3	2022
	29. Funding in RRFs earmarked for grid storage	higher score	-		2022
	30. Legislation reform connected to grids in RRF	higher score	-		2022
				100	

Note: RRF = Recovery and Resilience Facility

Limitations

Like all research, the Grid Transition Index is subject to certain limitations that must be acknowledged. These limitations arise from the inherent complexities of assessing diverse energy systems across multiple countries, the reliance on available data, and expert judgment in weighing various indicators. Understanding these constraints is essential for interpreting the index's results.

Relative scoring. The GTI's numerical scores and their division into four categories are inherently relative. Countries are assessed and ranked only in comparison to each other. For instance, there is no absolute threshold that separates "highly prepared" from "moderately prepared" countries. Therefore, when presenting a country's results, it is important to note that these are based on comparisons with the other 34 countries in the study.

Indicator weighting. To combine the 30 diverse indicators, weighting is necessary to reflect their varying degrees of importance. While quantitative methods such as data envelopment analysis could have been applied, they would have come at the cost of clarity in interpreting the results. Instead, in collaboration with the GLOBSEC Energy Advisory Committee, expert judgment was used to assign weights. It is understandable, however, that opinions on the "correct" weighting may vary.

Data limitations. The GTI draws from three primary data sources: Eurostat, ENTSOE, and European Resource Adequacy Assessments (ERAAs). These sources are widely recognized and used by businesses, NGOs, and research institutions, with detailed methodologies guiding their data collection. The most significant risk to data reliability comes from potential errors in data handling by the author. To mitigate this, great care was taken to ensure consistency, and all data handling was double-checked.

Forecast accuracy. A notable portion of the GTI is based on projections for the state of grids in 2030, derived from ERAAs based on modelling by TSOs. These forecasts may ultimately prove inaccurate, with the modelling potentially being too conservative or overly ambitious. Despite this, ERAA data remains the most reliable source available for predicting grid developments in 2030. Although alternative models exist, ERAAs have the advantage of being provided directly by TSOs, with a specific focus on electricity grids.

Outdated data. The most recent available data was used for all indicators, mainly from 2022 and 2023, which is sufficiently current to reflect conditions in 2024. However, the SAIFI indicator is an exception, with the latest available data from 2019, due to the discontinuation of the World Bank's Doing Business index. While some changes may have occurred in the past five years, this is addressed by assigning a relatively low weight to this indicator. Future versions of the GTI will incorporate more recent data for this metric.

Results

Immense ambitions meet grid limitations. The targets outlined by EU's TSOs in their adequacy assessments are truly ambitious. Integrating approximately 500 GW of new solar and 250 GW of new wind energy (Figures 2 and 3) within eight years is a monumental challenge, crucial for limiting global warming, enhancing energy security, and strengthening competitiveness. However, many countries are not yet prepared for this transition (Map 2). Some of them grapple with significant grid issues, even before the additional capacity from intermittent renewables and the reduction of flexible fossil sources. Detailed numeric results are available in Annex 3.

Notable gaps in preparedness for grid transition exist even among neighbouring countries, reflecting variations in energy policies as well as geographical conditions. For instance, Germany and France illustrate how differing approaches to nuclear energy can lead to diverging preparedness levels. While countries with favourable natural conditions — such as Spain and Portugal with their strong solar potential, or Austria and Sweden with significant water resources — enjoy certain advantages, those without optimal natural conditions, like Finland and Slovakia, can still achieve good results through effective policy and planning.

Map 2: Results of Grid Transition Index 2024

Source: GLOBSEC, mapchart.net

Even countries with highly ambitious targets can be well-prepared. Latvia, for example, has an above-EU average goal in new intermittent renewable generation. However, effective policy measures — such as extensive smart meter rollout and the development of interconnectors — have achieved results showing high preparedness.

Quartile Analysis – Preparedness Even with High Ambitions?

More ambitious countries do not necessarily achieve worse results. Two indicators (14 and 15) in the index assess countries based on their goals for deploying new renewable energy sources between 2022 and 2030. Countries with higher ambitions receive lower scores because the index focuses on grid preparedness for the transition. Increased intermittent renewable energy production requires more significant investments and presents greater challenges for the grid. While it might be expected that countries with lower ambitions could score higher in the index, this is not the case. Figure 4 illustrates that countries with more ambitious renewable energy goals do not tend to have lower index scores.

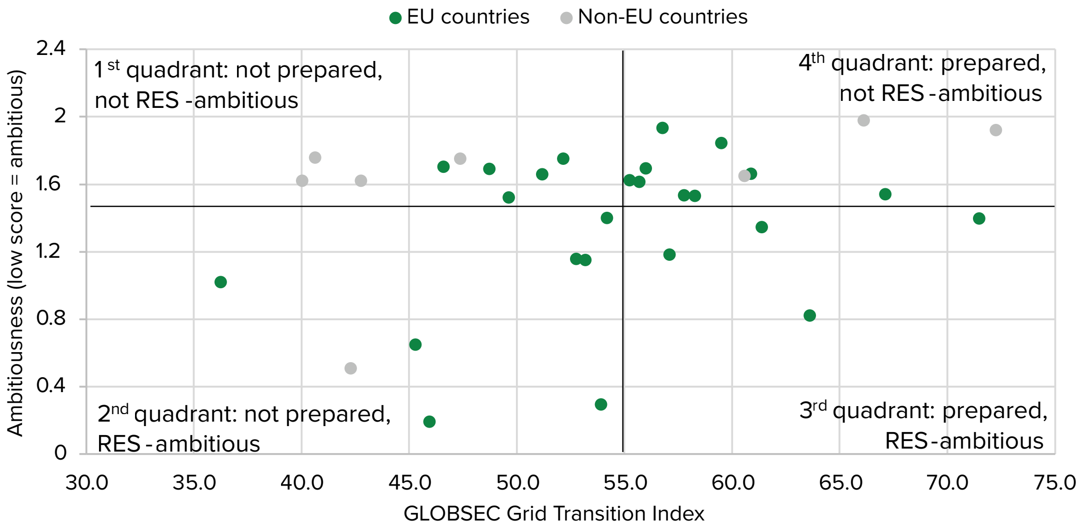
Countries can be categorized into four groups (quadrants) based on their level of preparedness and their ambitions to integrate renewable energy sources by 2030. This classification allows us to identify broader trends across diverse groups.

First Quartile: Low Preparedness and Low Ambition.[1] This group includes countries that are neither well-prepared nor ambitious in their plans for new RES integration. Predominantly found in Central Eastern Europe and the Western Balkans, these countries rely heavily on fossil fuels and have modest goals for increasing intermittent renewables by 2030. This approach poses risks to their climate objectives and may lead to higher system costs due to rising carbon prices. Addressing these long-term investment gaps should be a primary focus for policymakers in these regions.

Second Quartile: Low Preparedness and High Ambition.[2] Countries in this category are not well-prepared but have high ambitions for renewable energy integration by 2030. This group includes a mix of Western European nations with significant fossil resources, Denmark (which is already decarbonized but maintains high 2030 targets), and two Baltic states along with Montenegro. These countries must focus on improving grid preparedness to avoid jeopardizing their renewable goals and to maintain system stability and performance.

Third Quartile: High Preparedness and High Ambition.[3] This group consists of countries that are both well-prepared and highly ambitious regarding renewable energy deployment by 2030. These countries have made substantial investments in their energy systems and benefit from favourable geographical conditions for renewable energy. While they currently are high performers, it is es-

Figure 4: Countries divided by the index results and RES rollout by 2030



Note: Ambitiousness is defined as the rollout of new renewables between 2022 and 2030 (equal to the sum of indicators 14 and 15).

1 Greece, Czechia, Hungary, Romania, Poland, Bulgaria, Albania, Serbia, North Macedonia, Bosnia and Herzegovina.
2 Denmark, Ireland, Germany, Lithuania, Netherlands, Estonia, Montenegro.
3 Spain, Portugal, Austria, Latvia.

sential for them to continually review their energy policies to ensure that high levels of renewable integration do not compromise other KPIs of their grid systems.

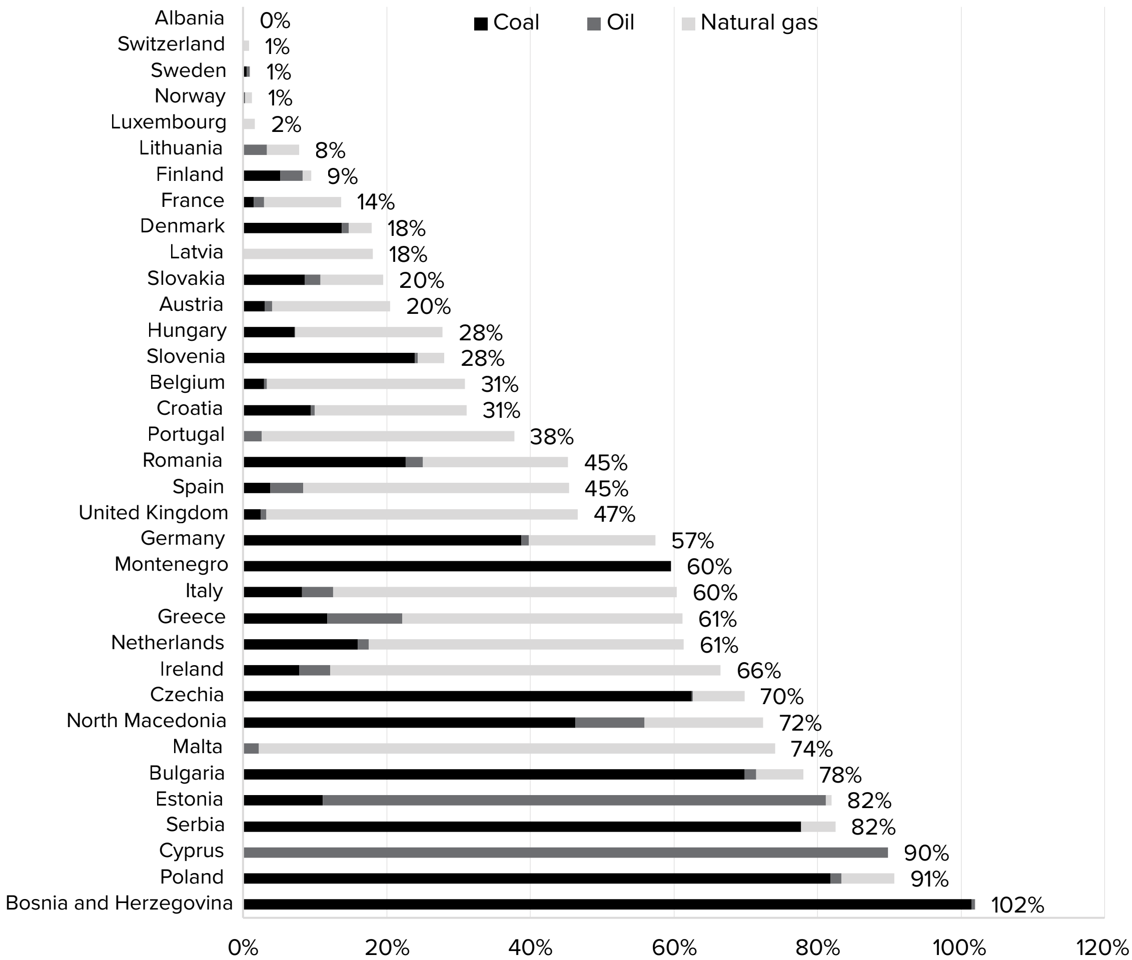
Fourth Quartile: High Preparedness and Low Ambition.[4] Countries in this category are well-prepared but have low ambitions for renewable energy integration by 2030. This diverse group often relies on nuclear power, reducing the need for renewables. While this strategy can be effective, these countries must ensure that any soon-to-be decommissioned nuclear facilities have viable alternatives, particularly in France and the UK. Additionally, although reliance on nuclear power may reduce grid development costs, it could increase government expenses due to the need for subsidies, especially for newly built nuclear.

On Average, More Than 40% of Electricity is Produced from Fossil Fuels

The utilization of fossil fuels in power generation differs significantly from the lowest share of fossil fuels in the world (Albania) to the highest share, which is close to 100%. Similarly, the mix of fossil fuels also differs notably, with Central and Eastern European countries (and Germany) tend to use more coal and Western European countries relying on natural gas.

A high reliance on fossil fuels threatens both competitiveness and price stability. In the EU, rising costs under the EU Emissions Trading System (ETS) make electricity generation from fossil fuels (particularly coal and oil) less competitive, driving up consumer prices. Furthermore, fossil fuel prices are subject to energy market fluctuations, leading to

Figure 5: Share of electricity produced from fossil fuels (normalized by electricity consumption)



Note: Due to a large share of exports, the percentage of Bosnia and Herzegovina exceeds 100%.

4 Luxembourg, Sweden, France, Belgium, Italy, Slovakia, Slovenia, Croatia, Finland, Switzerland, Norway, United Kingdom

increased volatility and higher costs during energy crises. While all electricity sources, including renewables, are priced based on the marginal cost (primarily that of natural gas), generating electricity with low fuel costs during energy crises can lead to substantial windfall profits for producers. This situation, in turn, increases government tax revenues and can be advantageous for the public.

The Gap in Renewables Deployment Levels Is Set to Widen

The gap in renewable deployment between countries is anticipated to widen further by 2030. Forecasts reveal substantial disparities in the projected increases in wind and solar capacity across different countries (Figure 6).

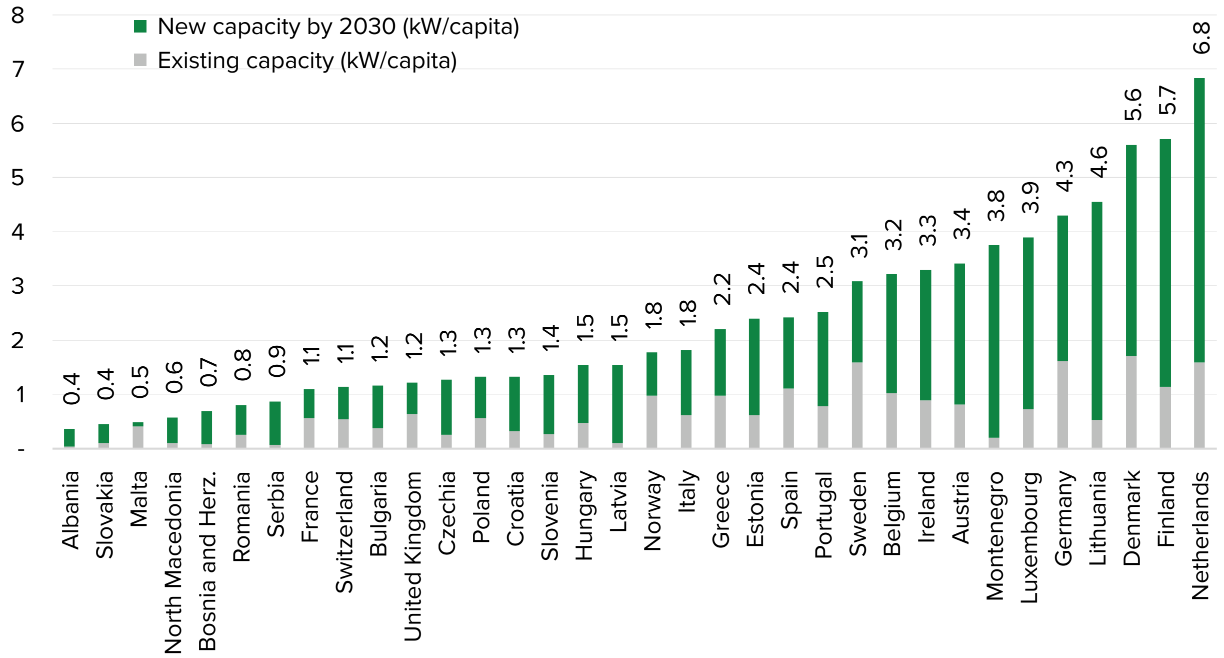
Countries with significant existing renewable capacity are planning to add the most new capacities, further widening the gap in renewable penetration. The index evaluates both the capacity and energy output of these renewables, as well as their impact on grid systems. However, it does not address the potential opportunity costs associated with *not* deploying highly cost-effective renewables. These costs include higher electricity prices, diminished industrial competitiveness, and implications for Environmental, Social, and Governance (ESG) criteria.

Slow Adoption of New Technologies May Increase System Costs

The disparity between countries in the adoption of new grid technologies is considerable. Although most countries anticipate some level of grid battery installation by 2030, the scale of these installations varies widely (Figure 7). The gap is even more pronounced in the area of demand response, with seven EU countries not expecting any demand response capabilities by 2030. Limited adoption of these technologies could drive up system costs and require more extensive physical infrastructure.

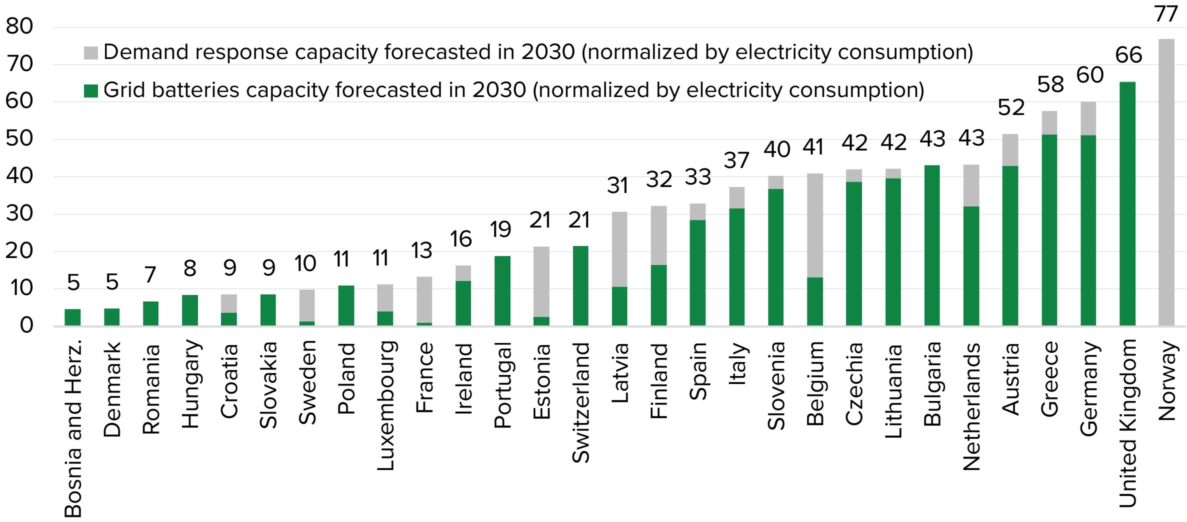
The forecasted demand response capacities show only a weak correlation with the current share of smart meters in households. This is surprising, given that smart metering is nearly essential for enabling demand response. For instance, Denmark projects no demand response capacity by 2030 despite already achieving full smart meter penetration. Conversely, Belgium, which had only 22% smart meter coverage in 2022, is expected to have the second-highest demand response by 2030. A similar disconnect between high-demand response forecasts and low smart meter rollout is evident in Germany and Greece. This suggests that an accelerated smart meter deployment may be necessary, potentially leading to sunk costs if new meters without smart attributes must be replaced with smart meters.

Figure 6: Intermittent renewable capacity by 2030, kW/capita



Source: ACER, Eurostat

Figure 7: Grid batteries and demand response in 2030, normalized by consumption (MW/TWh)



Note: North Macedonia, Serbia, Albania and Montenegro were excluded as they foresee no grid batteries or demand response capacities in 2030.

Source: ACER, GLOBSEC

Grid Transition Remains Sidelined in National Politics

At the national level, the issue of grid transition is often overlooked in policymaking. The Recovery and Resilience Facility (RRF) offered a prime opportunity to finance grid upgrades and introduce legislative reforms to enhance grid infrastructure. Given the energy price volatility caused by the Russian aggression in Ukraine, strengthening grids and integrating local renewable capacity seemed like a logical response. However, fewer than half of EU countries committed to legislative reforms aimed explicitly at advancing grid transition.

Several countries with low levels of preparedness did not address grid issues in their RRFs at all. Austria, Denmark, Germany, Ireland, and Luxembourg failed to prioritize grid transition in their plans, with Denmark, Germany, and Ireland receiving only a "partially prepared" ranking in the index.

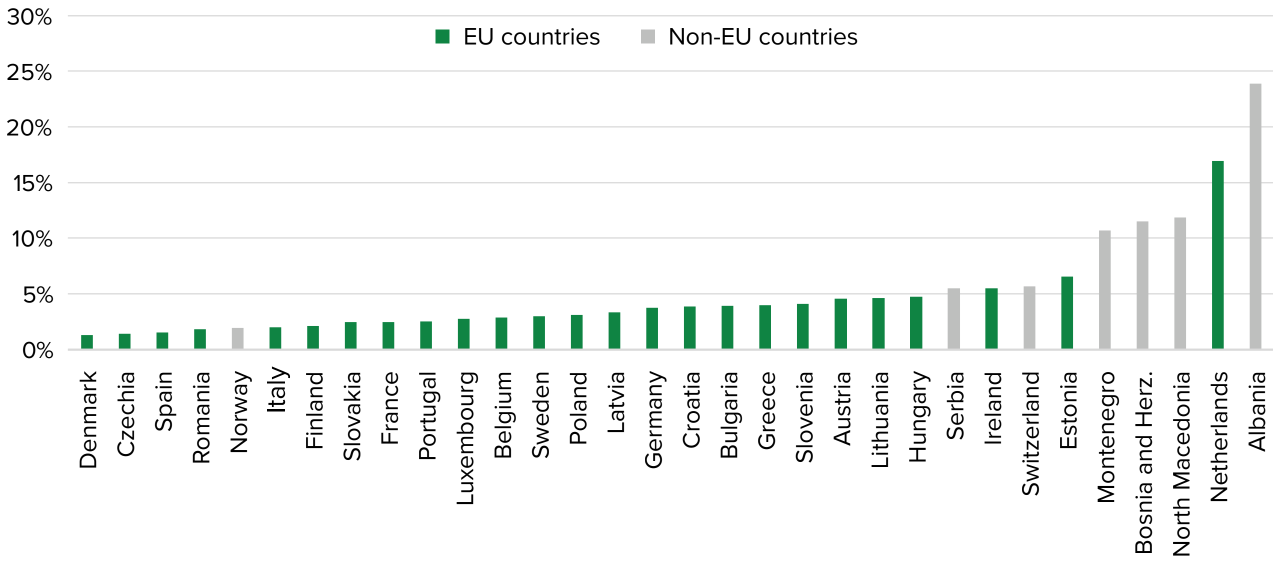
Fiscal constraints highlight the need to attract private capital and utilize EU funding to finance grid transition. Shifting the financial burden onto consumers, while possible in theory, would undermine the goals of the green transition. Such an approach would drive up electricity costs, reduce its competitiveness against fossil fuels, potentially raise emissions, and slow the electrification of sectors currently reliant on fossil fuels.

Financing challenges are particularly acute in the Western Balkans. Unlike EU countries, these countries cannot depend on substantial European funds for grid upgrades. High debt levels, costly borrowing, and aging infrastructure further complicate the situation. Nevertheless, grid modernization will be essential, particularly for those seeking EU membership, which would require adopting the EU carbon trading scheme, driving up costs for electricity—mostly generated from fossil fuels—and enhancing the business case for renewable energy sources.

Uneven Forecast Accuracies Reveals Opportunities for Cross-Country Learning

While some indicators show similar results across countries, others reveal significant disparities, highlighting a strong potential for mutual learning. For instance, day-ahead load forecasting accuracy varies greatly within the EU. Denmark's forecasts, for example, are 13 times more accurate than those of the Netherlands. In practical terms, the average forecasting error in the Netherlands exceeds 2,000 MW, which is equivalent to the output of two average-sized nuclear reactors. Such disparities underscore the considerable opportunities for countries to share best practices and improve grid performance.

Figure 8: Load forecast inaccuracy, average error compared to average load (2023)



Source: GLOBSEC, ENTSOE

Ten Policy Recommendations

1. **Solutions should be tailored to the specific contexts of each country.** The Index results show significant variation in the state of electricity grids across EU countries. While some policies, such as streamlined permitting and increased flexibility, are broadly applicable, others must account for national differences. For instance, renewable subsidies may be inefficient in a country with an unstable regulatory environment and crowded connection queues.
2. **In addition to investing in new grid infrastructure, regulations should incentivize the optimal use of existing assets.** Because of the high costs of building new infrastructure, lengthy development, and construction time, grid operators should also focus on maximizing the efficiency of current systems. For example, a standardized EU-wide methodology for calculating the permissible levels of renewable energy integration for TSOs and DSOs should be adopted. The refurbishment of existing grids and the adoption of a "flexibility first" approach should be encouraged.
3. **Long-term planning and anticipatory investments should be integral components of grid planning.** While developing a renewable energy project can take up to five years, establishing a grid connection may take up to three times longer. Therefore, long-term planning must involve a wide range of stakeholders, including governments, regulators, and investors. National regulatory agencies should be more dynamic and agile in the face of changes stemming from the green transition (Pollitt, Covatariu, Duma, 2024).
4. **Significant grid investments are necessary, but these should not be financed through electricity consumer tariffs,** as this would slow down the energy transition by increasing electricity costs. An estimated €584 billion in grid investment is needed by 2030 (EC, 2023). This funding can come from the Modernization Funds, the European Structural and Investment Funds or state budgets. Alternatively, regulators may consider funding electricity grids through gas tariffs as gas users will also have to eventually switch to using electricity in a decarbonized future.
5. **Grid investments should be preferred over subsidizing already competitive renewable resources.** The key bottleneck of renewables rollout is no longer their costs but the insufficient capacity of the grid. Directly subsidizing renewables may be, therefore, significantly less cost-effective.
6. **Permitting processes that have successfully accelerated renewable energy development should also apply to grid development.** This includes the use of "go-to zones," "no-go zones," tacit approval principles, and one-stop shops for permitting. Such principles should be incorporated into EU directives to ensure consistent processes for interstate projects.
7. **Electricity grids are of strategic importance, and policies should reflect this.** Just as some countries expedite permits for highway construction and other strategic projects due to their positive externalities, electricity grids should also benefit from a streamlined permitting regime. Additionally, regulators should consider increasing WACC rates used for TSOs and DSOs investments to motivate investments in grids, especially when using advanced technologies and cutting-edge infrastructure.
8. **Reforms are needed to enable broad participation in flexibility markets.** The lack of system flexibility increases the need for physical infrastructure, slows down renewable energy integration, and raises system costs. Policies should be adopted to allow a wide range of participants to offer flexibility services without imposing overly complex technical standards (REA, 2023: 35-36). Policies should be issued with a focus on regulatory stability.
9. **Connection queues should be radically transparent and reformed.** Data on the availability of free load capacity and potential renewable energy connections should be publicly accessible at a granular level (Pató, Cremona, Rosslowe, 2024). The traditional "first come, first served" system should be reformed to prioritize strategically important projects that can be connected the quickest, even if this requires terminating stalled projects that applied earlier (OFGEM, 2023).
10. **The security of the grids should be kept in mind when investing in them.** In recent years, a rising number of grid security incidents and cyber-attacks have occurred on critical infrastructure. Public utilities fall behind on an upskilled workforce and ability to promptly react to various threats.

Factsheets of EU Countries

Austria

(highly prepared)

Overview

- Austria is making **significant progress in decarbonizing its electricity grid,** leveraging its substantial hydroelectric potential.
- However, risks stem from notable **gas capacities,** especially in the context of a need to **decrease import reliance on Russia.**
- The **growth of intermittent renewable energy** sources by 2030 is projected to be **similar to the European average.**
- By 2030, Austria is expected to have **one of the highest levels of battery capacity** in Europe relative to its size.

Current Challenges and Electricity Markets

- The **share of coal and oil power plants in Austria is minimal,** and gas generation is also lower than the European average.
- There are ongoing **challenges in accurately forecasting electricity demand,** with **imbalance volumes higher** than the European average.

Challenges in 2030

- Despite a relatively moderate adoption of new renewable energy sources, Austria is expected to see a **substantial increase in battery storage capacity** (3.6 GW) and some **growth in demand response capabilities** (0.7 GW).
- Austria is likely to maintain **a high degree of capacity adequacy in 2030,** largely due to its large pumped hydro resources.

Opportunities

- Austria's **interconnector capacities are currently below** the European average.
- Issues related to grid transition **were not addressed** in Austria's Recovery and Resilience Facility.

Overall ranking: 4th / 25

Current challenges and electricity markets ranking: 6th / 25

Challenges in 2030 ranking: 3rd / 25

Opportunities ranking: 12th / 25

Strengths for Grid Transition

- High capacity adequacy in 2030 (the best)
- High capacity of pumped hydro (the 2nd best)
- High capacity of batteries in 2030 (the 3rd best)
- Low imbalance volume (the 5th best)
- Low generation from coal and oil (the 8th best)

Difficulties for Grid Transition

- Low stress on grid transition in the Recovery and Resilience Facility (the worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Belgium

(moderately prepared)

Overview

- Belgium has **a notably higher share of electricity generation from gas** compared to the EU average, with no significant decrease in capacity expected before 2030.
- The advantages of the Belgian grid includ**e low imbalance and low load variability.**
- Belgium is forecasted to be **a European leader in capacity for demand response** by 2030.

Current Challenges and Electricity Markets

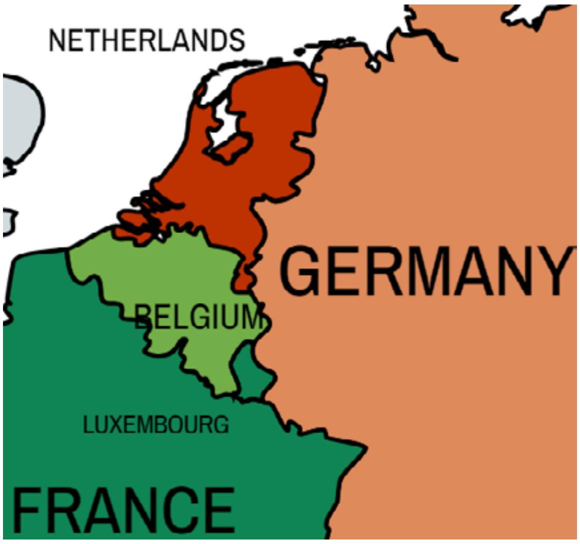
- The share of **coal and oil power plants in Belgium is negligible**.
- The Belgian grid suffers from **low flexibility,** evidenced by **high imbalance prices** and a relatively **high incidence of negative spot** prices.
- Most other market indicators, such as **SAIFI, grid losses, and load variability, are better** than the European average.

Challenges in 2030

- Belgian uptake of renewables by 2030 is expected to **be similar to the European average,** despite an anticipated **above-average demand growth.**
- To balance its grid, Belgium will rely extensively **on demand response (3.1 GW)** by 2030.
- However, **the capacity of grid batteries will be lower (1.5 GW)** and significantly below the EU average.

Opportunities

- The high share of demand response contrasts with **the relatively low uptake of smart meters** today (22.4%).



Overall ranking: 7th / 25

Current challenges and electricity markets ranking: 5th / 25

Challenges in 2030 ranking: 16th / 25

Opportunities ranking: 11th / 25

Strengths for Grid Transition

- High capacity of demand response in 2030 (the best)
- Low peak load (the best)
- Low load standard deviation (the best)
- Low imbalance volume (the 6th best)
- Low reliance on coal and oil generation (the 7th best)

Difficulties for Grid Transition

- Small hydro capacities

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Bulgaria

(not prepared)

Overview

- Bulgaria still **heavily relies on coal power plants,** even though it is the **largest electricity** exporter in Europe in relative terms.
- Bulgarian consumers suffer from **the highest occurrence of service interruptions** in the EU.
- Bulgaria anticipates a relatively modest increase in renewables, which suggests low challenges to the grid by 2030, but this could represent a **missed opportunity.**

Current Challenges and Electricity Markets

- The **average Bulgarian customer experiences five service interruptions yearly, the highest number in the EU.**

Challenges in 2030

- Bulgaria does not expect **significant challenges due to the low growth** of intermittent renewables.
- There is an ambitious target for battery storage rollout **by 2030** (1.6 GW).

Opportunities

- The high share of fossil fuels in Bulgaria's electricity mix is paradoxical given its status as **the highest electricity exporter** in the EU.
- The **rollout of smart meters in households is negligible.**

Overall ranking: 22nd / 25

Current challenges and electricity markets ranking: 24th / 25

Challenges in 2030 ranking: 2nd / 25

Opportunities ranking: 22nd / 25

Strengths for Grid Transition

- High export of electricity (the best)
- Low presence of negative spot prices (the 6th best)

Difficulties for Grid Transition

- Service interruptions (the worst)
- No smart meters in households (the worst)
- No demand response forecasted in 2030 (the worst)
- High peak load (the 2nd worst)
- High share of reliance on coal and oil generation (the 4th worst)
- Spot price volatility (the 6th worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Croatia

(moderately prepared)

Overview

- The **reliance on fossil fuels is relatively low** in Croatia.
- The Croatian grid **does not perform well in terms of the number of interruptions and grid losses.**
- The **capacity of intermittent renewables is below the EU average,** and future rollout is also projected to be below average.

Current Challenges and Electricity Markets

- Approximately 10% of Croatian generation comes from **coal power plants, with another 20% from natural gas.**
- Most other indicators **do not significantly** differ from those of other EU countries.

Challenges in 2030

- Further **integration of intermittent renewables** is expected to be **relatively limited.**
- **No significant uptake of grid batteries** is forecasted for 2030 (66 MW).
- There is **no forecasted capacity inadequacy** in 2030.

Opportunities

- Croatia lags behind in the adoption of **new technologies such as demand response and smart metering.**
- There is **a strong focus on grids** in Croatia's Recovery and Resilience Facility.

Overall ranking: 12th / 25

Current challenges and electricity markets ranking: 16th / 25

Challenges in 2030 ranking: 7th / 25

Opportunities ranking: 18th / 25

Strengths for Grid Transition

- Resource adequacy in 2030 (the best)
- Grid transition in recovery and resilience facility (the best)
- Low increase in demand growth (the 3rd best)

Difficulties for Grid Transition

- Low uptake of batteries in 2030 (the 5th worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Cyprus

(not prepared)

Overview

- **Approximately 90% of Cyprus's electricity** comes from oil.
- Despite favourable natural conditions, **Cyprus has low penetration of intermittent renewables.**
- By 2030, intermittent renewables are expected **to grow very slowly,** which may ease grid management but could increase costs for consumers.

Current Challenges and Electricity Markets

- Cyprus benefits from its relatively small size and high population density, which **reduces pressure on grid operators.**
- **Grid losses and interruptions in Cyprus are among the lowest** in the EU.

Challenges in 2030

- Some **events of resource inadequacy** are forecasted for 2030, but the rate is expected to be lower than the EU average.

Opportunities

- Cyprus currently **does not fully utilize its potential for solar energy,** and this is not expected to change by 2030.
- The uptake of **smart meters in households is currently close to zero.**

Due to data unavailability, Cyprus cannot be consistently compared with other countries. Taking into account available data, it is coded as "not prepared".

Strengths for Grid Transition

- Low grid losses (the 2nd best)
- Low service interruption (the 3rd best)

Difficulties for Grid Transition

- Highest share of oil generation (the worst)
- No smart metering in households (the worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Czechia

(partially prepared)

Overview

- Czechia has a high share of **electricity generated from fossil fuels** (70%), and the need to decarbonize will create **significant pressure on its grid** in the coming decades.
- The penetration of **renewables is currently low.**
- The uptake of new renewables by 2030 is expected to be **well below the EU average.**

Current Challenges and Electricity Markets

- Despite high fossil fuel generation, Czech power markets perform better than the European average, particularly in terms of **imbalance volume and load forecasting.**

Challenges in 2030

- **In terms of flexibility, Czechia will** primarily rely on grid batteries (2.9 GW).
- A relatively **high resource inadequacy** of three hours per year is forecasted for 2030.
- The Czech energy strategy **relies on new nuclear power,** but there are concerns about whether it can be developed quickly enough to replace decommissioned coal capacities.

Opportunities

- The current **penetration of renewables is significantly below** the European average.
- Similarly, **smart metering for households is non-existent** in Czechia.

Overall ranking: 18th / 25

Current challenges and electricity markets ranking: 17th / 25

Challenges in 2030 ranking: 11th / 25

Opportunities ranking: 25th / 25

Strengths for Grid Transition

- Low imbalance volume (the best)
- High load forecast accuracy (the 2nd best)
- Electricity exporter (the 3rd best)

Difficulties for Grid Transition

- No smart metering (the worst)
- High imbalance price (the 2nd worst)
- Low renewables penetration today (the 4th worst)
- High share of coal or oil generation (the 5th worst)
- Low resource adequacy in 2030 (the 7th worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Denmark

(partially prepared)

Overall ranking: 15th / 25

Current challenges and electricity markets ranking: 12th / 25

Challenges in 2030 ranking: 25th / 25

Opportunities ranking: 1st / 25

Overview

- Denmark is **the most ambitious country** in terms of grid transition, achieving the best results in the opportunities category.
- Its **unique combination** of intermittent renewables and bioenergy allows for **low fossil fuel generation** with no hydro capacity.
- The scope of Denmark's **grid transition is immense,** and current indicators suggest that its grid transition will be successful.

Current Challenges and Electricity Markets

- Denmark's electricity generation from **fossil fuels is significantly below the EU average.**
- Load management in Denmark is exemplary, with **load deviation better** than the EU average and **the best load forecasting** in the EU.
- However, **imbalance volume is relatively high,** and there is a notable **occurrence of negative spot prices.**

Challenges in 2030

- Despite Denmark's high ambitions for renewables, **the forecasted capacity for batteries (290 MW) is low.**
- Demand response is **forecasted to be non-existent.**
- With limited hydro potential, Denmark will rely on biomass **to balance its grid.**

Opportunities

- Danish **renewable penetration is already the highest in the EU,** and by 2030, this position is expected **to strengthen further.**
- Denmark has achieved **full penetration of household smart meters** and can rely on a high capacity of **interconnectors.**
- Despite the ambitious grid transition, **no measures related to grid transition** were included in the Danish RRF.

Strengths for Grid Transition

- High capacity of intermittent renewables today (the best)
- Load forecast accuracy (the best)
- High share of smart metering (the best)
- Low share of electricity produced from gas (the 6th best)
- Significant electricity exporter (the 3rd best)

Difficulties for Grid Transition

- High strain on electricity grids due to the growth of energy produced from intermittent renewables by 2030 (the worst)
- High demand growth by 2030 (the worst)
- No demand response (the worst)
- No emphasis on grids in Recovery and Resilience Facility (the worst)
- High strain on electricity grids due to the growth of intermittent renewables capacity by 2030 (the 3rd worst)
- Low battery capacity (the 7th worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Estonia

(not prepared)

Overview

- **Estonia heavily relies on oil shale** for electricity generation, and its replacement will **place significant stress** on the Estonian grid.
- The country plans to **increase reliance on intermittent renewables,** but **the lack of balancing capacities** (such as hydro and batteries) and **rising demand** will pose considerable challenges.
- Advantages include strong **interconnector** capacities and **extensive smart metering.**

Current Challenges and Electricity Markets

- In addition to high fossil fuel generation, Estonia faces issues such as **low load forecast accuracy, high losses, and varying load.**

Challenges in 2030

- Unlike many other Eastern EU member states, Estonia has set **high renewable goals** for 2030.
- Balancing these renewable sources **without fossil fuels will be challenging,** as Estonia cannot rely on hydro and anticipates limited battery capacity.

Opportunities

- **Demand response will play a significant role** (198 MW), and the **100% integration of smart metering** indicates that Estonia is making progress in this area.
- Despite the immense challenges to the Estonian grid transition, only **a small space was given to grids** in the Recovery and Resilience Facility.

Overall ranking: 25th / 25

Current challenges and electricity markets ranking: 25th / 25

Challenges in 2030 ranking: 22nd / 25

Opportunities ranking: 7th / 25

Strengths for Grid Transition

- High share of smart meters (the best)
- High share of interconnector capacity (the 3rd best)

Difficulties for Grid Transition

- High generation from coal or oil (the worst)
- Highest losses (the worst)
- Low load forecast accuracy (the 2nd worst)
- High imbalance (the 4th worst)
- Low battery capacity in 2030 (the 7th worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Finland

(moderately prepared)

Overview

- Finnish electricity generation **is highly decarbonized,** relying on nuclear, hydro, and wind energy.
- Integration of **renewables will progress at a pace comparable to other EU** countries.
- Negative spot **prices remain a challenge.**

Current Challenges and Electricity Markets

- Finland **excels in grid performance indicators** such as number of interruptions, grid losses, load forecast accuracy, and imbalance volumes.
- However, it has the highest prevalence of negative **spot prices in the EU.**

Challenges in 2030

- Growth in intermittent renewable capacity is expected to align with the EU average, with significant **expansion in onshore wind.**
- Finland will deploy **both demand response and batteries,** with capacities around 1.6 GW each.
- Despite substantial hydro potential, no pumped hydro **capacity is planned.**

Opportunities

- Finland's current **integration of renewables and interconnectors is below the EU** average.
- The country **has 100% penetration of smart metering in households.**

Overall ranking: 13th / 25

Current challenges and electricity markets ranking: 11th / 25

Challenges in 2030 ranking: 15th / 25

Opportunities ranking: 15th / 25

Strengths for Grid Transition

- Low number of interruptions (the best)
- High number of smart meters in households (the best)
- Low fossil fuel generation (the 3rd best)
- Low imbalance volume (the 4th best)

Difficulties for Grid Transition

- High occurrence of negative prices (the worst)
- High variability of day-ahead spot prices (the worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

France

(highly prepared)

Overview

- France's fleet of **nuclear power** plants enables it to decarbonize and rely less on intermittent renewables, which **reduces pressure on the French grid.**
- A key challenge will be **replacing nuclear reactors and increasing technical outage times** as they approach the end of their operational lifetime.

Current Challenges and Electricity Markets

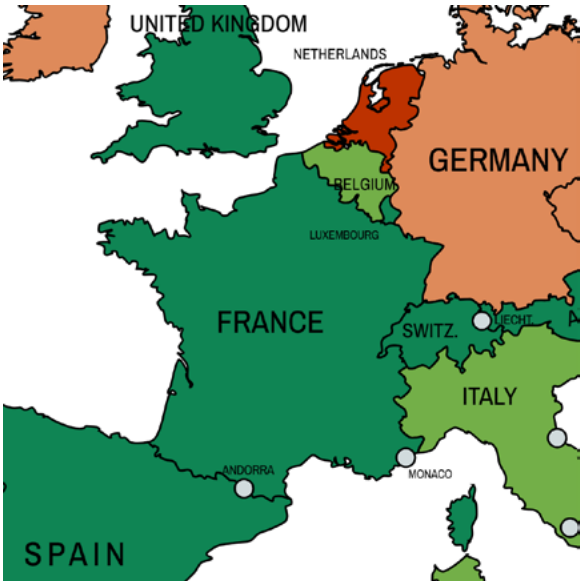
- Fossil fuel production in France is **significantly below the EU average.**
- Market indicators show **strong performance,** particularly in terms of imbalance volume, load forecast accuracy, and interruptions.
- **Grid losses** in France are above the average.

Challenges in 2030

- Compared to other EU countries, France forecasts **a limited rollout of new intermittent renewables.**
- The low rollout of renewables is also supported by **a relatively low increase in demand** by 2030.
- There is **very little forecasted rollout of grid batteries** by 2030 (470 MW).
- In contrast, **demand response is expected to exceed battery capacity** by more than 12 times (5.7 GW).

Opportunities

- Current **renewable rollout in France is significantly below** the EU average.
- **Interconnector capacity is limited** considering the size of the country.
- The prospects for demand response are enhanced by an already high share of **electricity used for heating and extensive smart metering.**



Overall ranking: 6^{th} / 25

Current challenges and electricity markets ranking: 3^{rd} / 25

Challenges in 2030 ranking: 13^{th} / 25

Opportunities ranking: 16^{th} / 25

Strengths for Grid Transition

- Low strain on electricity grids due to the low expected growth of energy produced from intermittent renewables by 2030 (the worst)
- Low fossil fuel generation (the 5^{th} best)
- Low interruption (the 5^{th} best)

Difficulties for Grid Transition

- Low rollout of batteries (the worst)

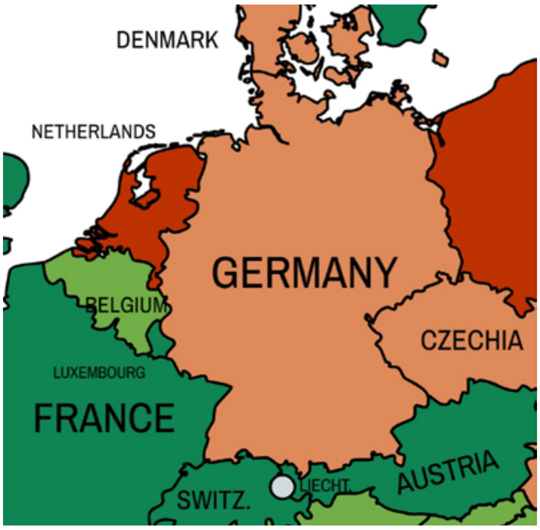
The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Germany

(partially prepared)

Overview

- The German grid faces **significant challenges** due to the nuclear phase-out.
- The grid will need to integrate **a substantial amount of new renewables,** with TSOs largely relying on grid **batteries** to manage this transition.
- There is **untapped potential in smart metering.**
- Germany **did not address the state** of its grid in the Recovery and Resilience Facility.



Overall ranking: 17th / 25

Current challenges and electricity markets ranking: 18th / 25

Challenges in 2030 ranking: 18th / 25

Opportunities ranking: 10th / 25

Current Challenges and Electricity Markets

- Germany's share of **fossil fuel use in electricity generation is one of the highest** in the EU, although the 2022 data does not fully reflect the nuclear phase-out.
- The share of hours with **negative spot prices is significantly higher than the EU average,** indicating insufficient flexibility.
- Conversely, electricity market indicators show **strong performance in terms of imbalance volume and interruptions.**

Challenges in 2030

- Germany has relatively **high ambitions for the rollout of new intermittent renewables** by 2030, but considering the country's size, it will not be extreme compared to the EU average.
- These renewable sources will need to be **integrated with minimal hydro** availability.
- Germany is forecasted to be the **leader in battery rollout by 2030** (29 GW).

Opportunities

- Germany performs **well in terms of opportunities,** largely due to its already high integration of renewables.
- There is a high potential for **smart metering adoption, which is currently virtually non-existent in Germany.**
- **No reforms or investments related to grid transition** are included in the German Recovery and Resilience Facility.

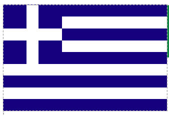
Strengths for Grid Transition

- High battery capacity 2030 (the best)
- Very low imbalance volumes 2022 (3rd best)
- Low peak load (the 3rd best)

Difficulties for Grid Transition

- Low capacity adequacy in 2030 (the 2nd worst)
- Very low smart metering (the worst)
- No grid transition reforms or investments in Recovery and Resilience facility (the worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."



Greece

(partially prepared)

Overview

- Greece relies **heavily on electricity from natural gas** and lacks ambitious decarbonization plans in this area.
- Less than **10% of gas capacity is expected to be decommissioned** before 2035.
- Currently, Greece utilizes **more intermittent renewables than the EU average.**
- The further growth of renewables is projected to be **at levels similar to the EU average.**

Current Challenges and Electricity Markets

- While the continued presence of extensive **gas capacities may enhance grid stability, consumers could face high electricity prices** due to rising carbon costs.
- Greece experiences **high load deviation,** which complicates the integration of renewables.

Challenges in 2030

- By 2030, Greece will heavily rely on **batteries,** with a forecasted capacity of **3.4 GW.**
- Thanks to the extensive rollout of batteries, **resource inadequacy in 2030 will be negligible.**

Opportunities

- Greece **lags significantly behind in terms of interconnector capacity and smart meter rollout.**
- However, the national **Recovery and Resilience Facility includes several investments and legislative changes** aimed at supporting grid transition.

Overall ranking: 14th / 25

Current challenges and electricity markets ranking: 22nd / 25

Challenges in 2030 ranking: 5th / 25

Opportunities ranking: 6th / 25

Strengths for Grid Transition

- Low occurrence of negative prices (the best)
- High rollout of batteries in 2030 (the best)
- High emphasis on grid transition issues in Recovery and Resilience facility (the best)
- Low resource inadequacy in 2030 (the 4th best)

Difficulties for Grid Transition

- High deviation of load (the worst)
- Low rollout of smart meters (the worst)
- High peak load (the worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Hungary

(moderately prepared)

Overview

- Hungary's **low reliance on fossil fuels** is primarily due to its significantly negative trade balance of electricity.
- Rise in demand will be covered by **new nuclear capacity** (2.3 GW) in Paks NPP supplied by Rosatom.
- **Natural gas installed capacity** is expected to grow by almost 1.5 GW before 2030.

Current Challenges and Electricity Markets

- The power market in Hungary **lags behind in several indicators,** including load forecasting and imbalance pricing.

Challenges in 2030

- Despite **limited growth of intermittent renewables anticipated by 2030,** there may be insufficient balancing capacities.
- Demand response and battery storage levels are forecasted to be **relatively low.**
- Hungary **will not possess significant hydro** capacity.
- Resource **inadequacy in 2030** is expected to be above the EU average.

Opportunities

- Hungary currently has notably **less renewable penetration compared to the EU average** and is projected to have **little new renewable capacity by 2030.**
- The growth of natural gas capacities may lead to **increased consumer prices.**
- Penetration of **smart meters in households is low.**

Overall ranking: 19th / 25

Current challenges and electricity markets ranking: 14th / 25

Challenges in 2030 ranking: 20th / 25

Opportunities ranking: 21st / 25

Strengths for Grid Transition

- High emphasis on grid transition issues in Recovery and Resilience facility (the best)

Difficulties for Grid Transition

- No demand response in 2030 (the worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Ireland

(partially prepared)

Overview

- Ireland's **geographical position complicates the decarbonization** of electricity generation.
- The country has relatively **ambitious targets for intermittent renewables.**
- New balancing capacities (such as demand response and batteries) will be **limited, with Ireland expected to primarily rely on natural gas for balancing.**

Current Challenges and Electricity Markets

- More than **half of Ireland's electricity generation comes from natural gas,** and its capacity is forecasted to grow mildly by 2030.
- The results in **peak load, load variability, and negative pricing are significantly better** than the EU average.
- **Low accuracy of load forecasting** remains a problem.

Challenges in 2030

- Ireland forecasts **higher integration of new intermittent renewables compared to the EU average.**
- However, the adoption of **batteries** (550 MW) and **demand response** (182 MW) will be **below** the EU average.

Opportunities

- Ireland has **limited interconnectors,** which adds to the complexities of its decarbonization efforts.
- Despite these challenges, **the Recovery and Resilience Facility does not include significant investments or reforms** to support grid transition.

Overall ranking: 16^{th} / 25

Current challenges and electricity markets ranking: 15^{th} / 25

Challenges in 2030 ranking: 21^{st} / 25

Opportunities ranking: 8^{th} / 25

Strengths for Grid Transition

- Low peak load (the best)
- Low average deviation of load (the 4^{th} best)

Difficulties for Grid Transition

- Reliance on generation from natural gas (the 2^{nd} worst)
- Low interconnector capacity (the 2^{nd} worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Italy

(moderately prepared)

Overview

- Natural **gas supplies almost half** of Italy's electricity generation.
- **No significant reduction in gas capacity** is forecasted before 2035.

Current Challenges and Electricity Markets

- Some **market indicators show high performance,** including load forecasting, imbalance volume, and low occurrence of negative prices.
- However, **imbalance prices are above the European average.**
- Italy experiences notably **more interruptions compared to the EU average.**

Challenges in 2030

- Despite its geographically advantageous position, Italy is expected to have **less intermittent renewable rollout compared to the EU average.**
- The country is already **below the EU average in renewable rollout.**
- Italy is forecasted to have **large capacities of grid batteries** (almost 11 GW) and **demand response** (2 GW), which are likely to decrease balancing costs in the medium term.

Opportunities

- Italy's **electricity exports, share of intermittent renewables, and existing pumped hydro capacity are somewhat below** the EU average.

Overall ranking: 8th / 25

Current challenges and electricity markets ranking: 9th / 25t

Challenges in 2030 ranking: 10th / 25

Opportunities ranking: 19th / 25

Strengths for Grid Transition

- No negative spot prices (the best)
- High load forecast accuracy (the 5th best)
- High smart metering rollout (the 7th best)

Difficulties for Grid Transition

- Load standard deviation (the 2nd worst)
- Low interconnector capacity (the 4th worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Latvia

(moderately prepared)

Overview

- Latvia's **intermittent renewable capacity is very low,** but the carbon intensity of electricity generation is low due to its **hydro capacities.**
- Significant **electricity production from gas continues,** with no forecasted decrease in gas capacity before 2035.

Current Challenges and Electricity Markets

- **Interruptions, losses and peak load in the Latvian electricity grid are below** the EU average.
- However, **load deviation is relatively high**.

Challenges in 2030

- Despite high hydro production, Latvia **does not have pumped hydro capacities.**
- A significant **rise in demand response is expected,** with its capacity anticipated to be twice as high as battery capacity in 2030.
- Latvia has **very low penetration of intermittent renewables, and growth by 2030 is expected to be below the EU average.**
- Although **the low penetration of renewables may benefit the grid, it could lead to higher costs for consumers.**

Opportunities

- Latvia has **significant interconnector capacities** relative to its size.
- The **very high rollout of smart meters** in households enhances the prospects for demand response.

Overall ranking: 9th / 25

Current challenges and electricity markets ranking: 13th / 25

Challenges in 2030 ranking: 8th / 25

Opportunities ranking: 14th / 25

Strengths for Grid Transition

- No electricity production from coal or oil (the best)
- High hydro capacity (the best)
- High interconnector capacities (the best)
- High demand response capacity in 2030 (the 5th best)
- Low demand growth (the 5th best)

Difficulties for Grid Transition

- No pumped hydro capacity (the worst)
- Low penetration of renewables today (the 2nd worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Lithuania

(not prepared)

Overview

- Lithuania **imports 75%** of its electricity, resulting in low resilience in its electricity market.
- This **high level of imports** has allowed Lithuania to maintain low consumption of fossil fuels.
- The country is addressing these challenges with **the most ambitious intermittent renewable strategy in the EU,** which places high stress on its grid.

Current Challenges and Electricity Markets

- **Imbalance volume in Lithuania is the highest in the EU,** leading to increased balancing costs and worsening prospects for renewable integration.

Challenges in 2030

- Lithuania's **ambitions** for new intermittent renewable capacity are **the highest** in the EU.
- More than **11.5 GW of new intermittent renewables** are forecasted to be deployed by 2030.
- Balancing this capacity will be very challenging, with Lithuania planning to install **650 MW** of batteries by 2030, **significantly exceeding the EU average.**

Opportunities

- The significant rollout of new intermittent renewables is **notable given that current Lithuanian renewable capacity is below the EU average.**
- If successful, Lithuania's renewable **capacity per capita could be the fourth largest** in the EU by 2030.
- The country can rely on **extensive interconnector capacities** relative to its size.

Overall ranking: 23rd / 25

Current challenges and electricity markets ranking: 19th / 25

Challenges in 2030 ranking: 24th / 25

Opportunities ranking: 20th / 25

Strengths for Grid Transition

- Low fossil fuel generation (the 3rd best)

Difficulties for Grid Transition

- High imbalance volume (the worst)
- High strain on electricity grids due to the growth of energy produced from intermittent renewables by 2030 (the worst)
- Negative trade balance in electricity (the 2nd worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Luxembourg

(highly prepared)

Overview

- Luxembourg's small size and **significant interconnector capacity** enable it to **import 89%** of its electricity.
- Generation **from fossil fuels is negligible** due to this high level of imports.
- The country can also rely on **extensive pumped hydro capacity.**

Current Challenges and Electricity Markets

- Luxembourg excels in **low grid losses and a small number of interruptions** due to its low size and high density.

Challenges in 2030

- Luxembourg is expected to experience **the lowest demand growth by 2030 compared to other EU countries.**
- Challenges in **resource adequacy are anticipated** in 2030 due to the country's strong reliance on electricity imports and potential issues abroad.
- The expected **deployment of intermittent renewables by 2030 is somewhat below** the EU average.

Opportunities

- The current **penetration of intermittent renewables is relatively low.**
- Luxembourg has the highest **capacity of interconnectors in the EU,** reflecting its significant level of imports.

Overall ranking: 2nd / 25

Current challenges and electricity markets ranking: 2nd / 25

Challenges in 2030 ranking: 1st / 25

Opportunities ranking: 9th / 25

Strengths for Grid Transition

- Low fossil fuel generation (the best)
- Low occurrence of negative costs (the best)
- Low forecasted demand growth (the best)
- High pumped hydro capacity (the best)
- High capacity of interconnectors (the best)
- Low grid losses (the best)
- Low interruptions (the 3rd best)

Difficulties for Grid Transition

- Negative trade balance in electricity (the worst)
- No emphasis given to grid transition in Recovery and Resilience Facility (the worst)
- Low capacity adequacy in 2030 (the 2nd worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Malta

(not prepared)

Overview

- Electricity generation from **natural gas in Malta is the highest in the EU.**
- Natural gas capacity is expected to **increase by 50%** by 2030.
- **Solar PV,** the only potential intermittent source, **is not forecasted to grow** between 2026 and 2035.
- Despite its small geographical size and high population density, **Malta's grid losses are around the EU average.**
- **No rollout of batteries or demand response** is anticipated before 2030.
- Malta is projected to experience **the highest resource inadequacy** in the EU, with 27 hours per year forecasted where supply will not meet demand.
- The rollout of **electricity heating is the highest in the EU, and smart meters are relatively common, which could support demand response** measures.

Due to data unavailability, Malta cannot be consistently compared with other countries. Taking into account available data, it is coded as "not prepared".

Strengths for Grid Transition

- High share of heating served by electricity (the best)
- High rollout of smart meters in households

Difficulties for Grid Transition

- No expected capacity of batteries and demand response in 2030 (the worst)
- High forecasted resource inadequacy (the worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Netherlands

(not prepared)

Overview

- The Dutch grid faces **significant challenges,** particularly with grid congestion and the inability to connect new loads in several areas.
- Currently, the Netherlands covers over **40% of its electricity consumption through natural gas** generation.
- There are **plans to reduce natural gas capacity by a quarter by 2035,** replacing it with renewables.
- Given the grid congestion and other issues, this **grid transition is highly ambitious.**

Current Challenges and Electricity Markets

- The **ability to forecast load in the Netherlands is very low,** significantly worse than even the second worst EU country.
- The **variance of load is the lowest** in the EU.
- **Negative spot prices** are relatively common.

Challenges in 2030

- Dutch ambitions **for intermittent renewable deployment are unmatched.**
- The Netherlands plans to **deploy 94 GW of new intermittent renewables by 2030.**
- This would make the Netherlands the country with **the highest per capita capacity of renewables** by a 20% margin.
- To integrate these resources, the Netherlands plans for **above-average integration of grid battery storage (4.9 GW) and demand response (1.7 GW).**
- However, integrating intermittent renewable sources may still be **challenging with the decreasing capacity of flexible units.**

Opportunities

- Renewables **integration is already relatively high.**
- The Netherlands has **a relatively high share of smart metering.**

Overall ranking: 24th / 25

Current challenges and electricity markets ranking: 23rd / 25

Challenges in 2030 ranking: 23rd / 25

Opportunities ranking: 5th / 25

Strengths for Grid Transition

- Low standard deviation of load (the best)

Difficulties for Grid Transition

- Low load forecast accuracy (the worst)
- High strain on electricity grids due to the growth of energy produced from intermittent renewables by 2030 (the 2nd worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Poland

(not prepared)

Overview

- Poland heavily **relies on coal** for electricity production, and with increasing carbon costs, consumer prices are expected to rise.
- Coal **capacities are projected to decrease** by approximately 50% between 2030 and 2035.
- The decline in coal production is anticipated to be largely **replaced by intermittent renewables.**
- The first Polish **nuclear capacity is expected to come online** between 2030 and 2035, totalling 2.2 GW.

Current Challenges and Electricity Markets

- Poland has **the highest imbalance volume** in Europe, making financing for balancing increasingly difficult as coal units retire.
- Due to stable coal production, **electricity spot prices are less volatile** compared to the EU, and **negative prices are uncommon.**

Challenges in 2030

- Although retiring coal units will be replaced mainly by intermittent renewables, **their expected growth is below the EU average.**
- Poland does not anticipate **any demand response capacity** by 2030.

Opportunities

- **Smart metering** is limited in Poland, and electric heating is almost non-existent, which may explain the lack of expected demand response.
- Poland **cannot rely on significant interconnectors** due to its relative size.
- There is a significant **emphasis on grid transition in the Polish Recovery and Resilience Facility.**

Overall ranking: 21st / 25

Current challenges and electricity markets ranking: 21st / 25

Challenges in 2030 ranking: 17th / 25

Opportunities ranking: 17th / 25

Strengths for Grid Transition

- High emphasis on grid transition in Recovery and Resilience Facility (the best)
- Low peak load (the 5th best)

Difficulties for Grid Transition

- High production of electricity from coal (the worst)
- High imbalance volume (the worst)
- Low expected demand response in 2030 (the worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Portugal

(highly prepared)

Overview

- Approximately 35% of Portuguese electricity generation **comes from natural gas**. Portugal plans to cut its gas capacity by half before 2035.
- This reduction will be offset **by intermittent renewables,** with Portugal set to build the second most new renewable capacity in the EU relative to its size by 2030.
- To balance these new renewables, Portugal will primarily depend **on pumped hydro capacities.**

Current Challenges and Electricity Markets

- The **imbalance volume in Portugal is the second highest in Europe,** which could be exacerbated by further rollout of intermittent renewables.
- Despite **a high share of intermittent renewables,** Portuguese spot markets do not experience negative power prices.

Challenges in 2030

- The growth of **renewable capacity in Portugal will be approximately on par** with the EU average.
- However, due to excellent conditions and high capacity factors, **the growth in new renewable energy production will be the second highest** in the EU.
- Portugal **does not anticipate any demand response capacity** by 2030, and **battery capacity** is expected to be roughly at the EU average (990 MW).

Opportunities

- Portugal is already **successful in integrating significant intermittent renewable** capacities.
- Despite favorable geographic conditions, **the use of electricity for heating is very limited.**

Overall ranking: 3rd / 25

Current challenges and electricity markets ranking: 8th / 25

Challenges in 2030 ranking: 12th / 25

Opportunities ranking: 3rd / 25

Strengths for Grid Transition

- Low occurrence of negative prices (the best)
- Low loss of load expected in 2030 (the 3rd best)
- High hydro capacity

Difficulties for Grid Transition

- High strain on electricity grids due to the growth of energy produced from intermittent renewables by 2030 (the 2nd worst)
- Low demand response expected in 2030 (the worst)
- High imbalance volume (the 2nd worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Romania

(not prepared)

Overview

- Generation of **electricity from fossil sources in Romania is approximately at the EU average.** Romania plans to **expand** its gas capacities by 2,000 MW within a couple of years.
- Several market indicators in Romania **are alarming.**

Overall ranking: 20th / 25

Current challenges and electricity markets ranking: 20th / 25

Challenges in 2030 ranking: 14th / 25

Opportunities ranking: 13th / 25

Current Challenges and Electricity Markets

- **Imbalance volumes** are high, combined with **the highest balancing costs** in the EU, leading to increased prices for consumers.
- **Interruptions and grid losses, and price volatility** are all worse than the EU average.

Challenges in 2030

- **Forecasted growth of renewables is somewhat lower** than the EU average.
- Despite high imbalance prices encouraging balancing solutions, Romania forecasts **small growth in batteries and no growth in demand response.**
- Increasing **gas capacities are expected to prevent loss of load in 2030.** However, continuing reliance on fossil fuels may **increase system costs,** particularly with rising carbon costs.

Opportunities

- **Smart meter rollout** is limited, and the use of electricity for heating is negligible.
- Romania **extensively addresses** grid challenges in its Recovery and Resilience Facility.

Strengths for Grid Transition

- No expected loss of load in 2030 (the best)
- High emphasis on grid transition in Recovery and Resilience Facility (the best)
- Low deviation of load (the 3rd best)
- Low peak loads (the 4th best)

Difficulties for Grid Transition

- High imbalance prices (the worst)
- No demand response expected in 2030 (the worst)
- Little heating served by electricity (the worst)
- High number of interruptions (the 2nd worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Slovakia

(moderately prepared)

Overview

- Slovak electricity generation is **largely decarbonized** due to extensive nuclear capacities.
- Both the current capacity of **renewables** and the growth of renewables by 2030 **are the smallest in the EU.**

Challenges today and electricity markets

- Most **market indicators are better than the EU** average, including the accuracy of imbalance volume, load forecast, peak load and load deviation.

Challenges in 2030

- The **forecasted growth of renewables is the lowest** in the EU.
- This limited growth is linked to **a timid expansion of balancing capacities, with 266 MW of battery storage** expected by 2030 and no demand response anticipated.

Opportunities

- In this category, Slovakia's results are **significantly worse** compared to other categories.
- This is due to the **smallest relative integration of intermittent renewables** within the EU and relatively low smart metering penetration.
- However, the Slovak Recovery and Resilience Facility includes **several investments and reforms aimed at grid transition.**

Overall ranking: 10th / 25

Current challenges and electricity markets ranking: 7th / 25

Challenges in 2030 ranking: 6th / 25

Opportunities ranking: 23rd / 25

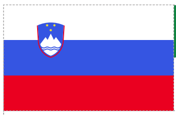
Strengths for Grid Transition

- High emphasis given to grid transition in the Recovery and Resilience Facility (the best)
- Low ambitions for renewable energy (the best)
- Low fossil fuel use (the 4th best)
- Low peak load (the 4th best)
- Low load deviations (the 5th best)

Difficulties for Grid Transition

- Low rollout of renewables today (the worst)
- No expected demand response in 2030 (the worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."



Slovenia

(moderately prepared)

Overview

- Slovenian electricity generation uses **somewhat less fossil fuels** than the EU average.
- This is primarily due to a combination of **nuclear and hydro** capacities.

Challenges today and electricity markets

- Slovenia faces **the highest imbalance volumes** in the EU.
- Despite challenging terrain, Slovenia has **one of the lowest numbers of interruptions and grid losses** below the EU average.

Challenges in 2030

- Slovenia **does not have ambitious plans for further deployment** of intermittent renewables.
- However, **a significant increase in battery capacity is forecasted,** reaching over 600 MW by 2030.
- Despite a relatively **high penetration of smart metering, no demand response** is forecasted for 2030.

Opportunities

- Current **penetration of renewables in Slovenia is one of the lowest** in the EU.
- Compared to other East European countries, Slovenia has **one of the highest penetrations of smart metering.**

Overall ranking: 11th / 25

Current challenges and electricity markets ranking: 10th / 25

Challenges in 2030 ranking: 4th / 25

Opportunities ranking: 24th / 25

Strengths for Grid Transition

- Low number of interruptions (the 4th best)
- Low expected loss of load (the 4th best)
- High forecasted growth of batteries (the 6th best)

Difficulties for Grid Transition

- High imbalance volume (the worst)
- Low integration of intermittent renewable today (the 3rd worst)
- High load deviation (the 3rd worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Spain

(highly prepared)

Overview

- Spain already uses **extensive capacities of intermittent renewables,** which are balanced by gas power plants.
- Despite significant renewable generation, **many key market indicators are among the best in the EU** (e.g., low imbalance volume, no negative prices).

Challenges today and electricity markets

- Spain has **the third-best forecast of load** in the EU, which supports further integration of renewables.
- The **capacity of gas power plants is not expected to decrease** by 2035.

Challenges in 2030

- The **further rollout of Spanish renewables will be similar to the EU** average.
- The rollout of both **batteries** and **demand response** is ambitious, with a forecasted cumulative capacity of 9 GW by 2030.

Opportunities

- Spain **cannot rely on extensive interconnectors** with surrounding countries, particularly given its relative size.
- **Rollout of smart meters** is high.
- **A number of reforms and investments** within the Recovery and Resilience Facility have been earmarked for grid transition.

Overall ranking: 1st/ 25

Current challenges and electricity markets ranking: 1st / 25

Challenges in 2030 ranking: 9th / 25

Opportunities ranking: 2nd / 25

Strengths for Grid Transition

- Low imbalance volume (the lowest)
- Low occurrence of negative prices (the best)
- High emphasis on grid transition in the Recovery and Resilience Facility (the best)
- High load forecast accuracy (the 3rd best)

Difficulties for Grid Transition

- Low capacity of interconnectors (the 4th worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Sweden

(highly prepared)

Overview

- Sweden has already **effectively decarbonized** its electricity generation thanks to its mix of hydro, nuclear, and wind energy.
- The primary challenge is the **growing demand,** which is forecasted to rise by more than 60% by 2030.

Challenges today and electricity markets

- **Day-ahead price volatility in Sweden is the lowest** in the EU, as is the **imbalance price,** indicating strong system flexibility likely supported by reservoir hydro.
- On the other hand, **negative prices are quite prevalent.**

Challenges in 2030

- Sweden **anticipates renewable growth that is somewhat below the EU average** but aims to meet the **rising demand of 60%** by 2030.
- The country is forecasted to face **resource inadequacy of more than 3 hours per year** by 2030, potentially necessitating some form of capacity markets.
- **Battery capacity is expected to be relatively low,** not exceeding 300 MW by 2030.

Opportunities

- Sweden's **current integration of intermittent renewables is above the EU average.**
- The country is **a net exporter of electricity.**
- **Smart metering penetration is at 100%,** supporting efficient grid management and potentially aiding in demand response.

Overall ranking: 5th / 25

Current challenges and electricity markets ranking: 4th / 25

Challenges in 2030 ranking: 19th / 25

Opportunities ranking: 4th / 25

Strengths for Grid Transition

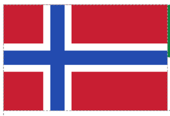
- Low generation from fossil fuels (the best)
- Low price volatility (the best)
- Low imbalance price (the best)
- High share of smart metering (the best)

Difficulties for Grid Transition

- High occurrence of negative spot prices (the 2nd worst)
- Low battery capacity in 2030 (the 2nd worst)

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted. Given similar political contexts, comparisons are made within a group of 25 EU countries, excluding Cyprus and Malta due to data limitations. In the "Strengths" and "Difficulties for Grid Transition" sections, multiple countries may share the same rankings, resulting in more than one country being identified as the "best" or "worst."

Factsheets of Non-EU Countries



Norway

(highly prepared)

Overview

- Norway has **successfully decarbonized its electricity generation** through a robust mix of hydro and wind power.
- The country's **ambitions for expanding new intermittent renewable energy sources are modest,** minimizing additional strain on the Norwegian grid.
- However, **Norway leads in 2030 targets for demand response capacity.**

Challenges today and electricity markets

- The Norwegian grid performs well in terms of **imbalance volume and load forecast.**
- Despite low population density in certain regions, **grid losses are below the EU average.**
- High levels of electric heating contribute to **significant load deviations and a high peak demand.**

Challenges in 2030

- Norway anticipates **electricity demand growth exceeding the EU average.**
- This increased demand is expected **to be met by expanding hydroelectric capacity,** with a lesser focus on intermittent renewables.
- The country has set **highly ambitious demand response targets** for 2030.
- **No battery capacities** in 2030 are forecasted.

Opportunities

- Current **generation from intermittent renewables in Norway is below the EU average.**
- Norway benefits from **substantial interconnections with neighbouring countries.**
- The share of electricity use in **heating is very high** and coupled with **extensive smart metering enables high levels of demand response in future.**

Scoring - compared to the 25 EU countries

Overall ranking: top 5%

Current challenges and electricity markets ranking: top 40%

Challenges in 2030 ranking: the best

Opportunities ranking: top 20%

Strengths for Grid Transition

- Low generation from fossil fuels
- Low imbalance volume
- High precision of load forecasts
- High share of demand response in 2030
- Low strain on electricity grids due to the low new rollout of intermittent renewables by 2030
- High share of electricity usage in heating
- High share of smart metering

Difficulties for Grid Transition

- High deviation of load

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted.

Switzerland

(highly prepared)

Overview

- Compared to even the best EU countries, **Switzerland excels across all categories.**
- Swiss **electricity generation is largely decarbonized,** driven by a mix of hydro, nuclear, and renewable sources.
- Beyond rising electricity consumption, Swiss **generation must expand** due to the projected decrease in nuclear capacity.
- New capacities by 2030 will be primarily in **solar PV and hydro.**

Challenges today and electricity markets

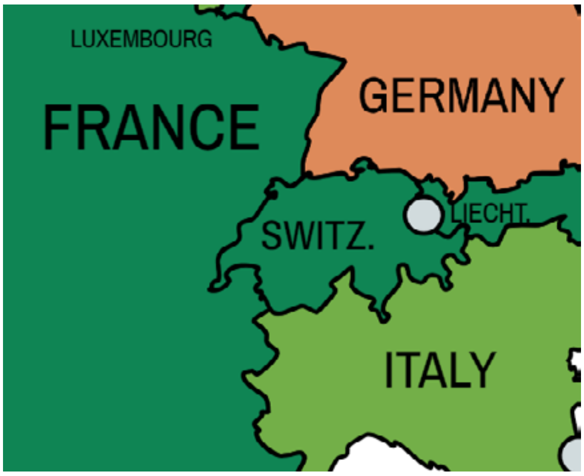
- While the Swiss grid has **very low load standard deviation and peak load, its load forecast accuracy falls below** the EU average.
- Indicators for **price volatility and negative prices are significantly better** than the EU average.

Challenges in 2030

- Although Switzerland expects **growth in intermittent renewables,** particularly solar PV, this growth is considerably **below the EU average.**
- **No demand response is anticipated,** but **battery capacity is expected to exceed 1 GW** by 2030.

Opportunities

- Switzerland currently has a relatively **low share of intermittent renewables,** raising questions about the potential for further integration.
- However, the country benefits from **extensive pumped hydro storage.**



Scoring - compared to the 25 EU countries

Overall ranking: the best

Current challenges and electricity markets ranking: the best

Challenges in 2030 ranking: the best

Opportunities ranking: top 40 %

Strengths for Grid Transition

- Low generation from fossil fuels
- Low number of interruptions
- Low deviation of load
- Low imbalance prices
- Low new rollout of intermittent renewables by 2030
- High share of demand response in 2030

Difficulties for Grid Transition

- No demand response in 2030
- Low rollout of intermittent renewables today

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted.

United Kingdom

(highly prepared)

Overview

- The United Kingdom continues to rely heavily on **electricity generation from fossil gas.**
- The forecasted growth of **intermittent renewables remains below the EU average.**
- Over **20 GW of new offshore wind capacity** is expected by 2030, alongside **7 GW of onshore wind** and some nuclear additions.
- **Rising demand and the planned decommissioning** of several nuclear reactors in the coming years present significant challenges.
- The anticipated increase in intermittent renewables is expected to be supported by a **substantial rollout of battery capacity and demand response measures.**
- Achieving demand response targets may be challenging, given **the low prevalence of electric heating and the relatively limited adoption of smart meters.**

Scoring - compared to the 25 EU countries

Overall ranking: top 20%

Current challenges and electricity markets ranking: top 50%*

Challenges in 2030 ranking: top 20%

Opportunities ranking: top 30%

Strengths for Grid Transition

- High share of battery capacity in 2030
- Low incidence of interruptions

Difficulties for Grid Transition

- Low capacity of all types of hydro in 2030

** Compared to other non-EU countries, there is a higher share of data unavailability in the case of United Kingdom due to the missing data on the ENTSOE Transparency Platform.*

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted.

Albania

(not prepared)

Overview

- Albania's electricity **generation is fully decarbonized,** primarily due to extensive hydro capacities, but **electricity market indicators show very poor performance.**
- The targets for **new intermittent renewable integration are relatively modest.**
- A new **300 MW natural gas capacity is forecasted,** likely due to the absence of other balancing technologies such as batteries and demand response.

Challenges today and electricity markets

- Albania's electricity market performance is **the weakest, even when compared to other Western Balkan countries.**
- This poor performance is evident in **load forecast accuracy, service interruptions, imbalance volume, and deviations in load and peak load.**
- For instance, the average number of service interruptions in the EU **is around 1, whereas in Albania, it is 22.**

Challenges in 2030

- Albania shows relatively good results in this category, largely due to its **limited ambitions for intermittent renewables and extensive hydro capacities.**
- However, **no battery or demand response capacity** is forecasted for 2030.
- Instead, Albania plans **to rely on new natural gas capacities.**

Opportunities

- Albania's low performance stems from the **minimal integration of intermittent renewables, lack of smart metering, and absence of pumped hydro capacities.**

Scoring - compared to the 25 EU countries

Overall ranking: bottom 20%

Current challenges and electricity markets ranking: bottom 20%

Challenges in 2030 ranking: top 10%

Opportunities ranking: the worst

Strengths for Grid Transition

- No electricity generation from fossil fuels
- Low imbalance price
- High share of electrical heating
- High capacity adequacy in 2030

Difficulties for Grid Transition

- Low accuracy of demand forecast
- High number of interruptions
- High imbalance volume
- High deviation of load
- High peak load
- No forecasted battery or demand response capacity in 2030
- Low share of intermittent renewables today
- Low share of smart metering

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted.

Bosnia and Herzegovina

(not prepared)

Overview

- Bosnia and Herzegovina **exports electricity equivalent to 30%** of its consumption but remains heavily dependent on coal power plants.
- No **fossil fuel power plant decommissioning** is anticipated before 2035.
- The country exhibits **low performance across key electricity market indicators.**

Challenges today and electricity markets

- Like other Western Balkan countries, Bosnia and Herzegovina **ranks poorly in imbalance volume, load forecasting, and load deviation,** even compared to low-performing EU countries.
- However, the country experiences **very few electricity supply interruptions,** at half the EU average.

Challenges in 2030

- The planned **rollout of new intermittent renewables is relatively modest.**
- The projected **increase in electricity demand is the lowest** in the Western Balkan region.
- Although the forecasted **battery capacity for 2030 is low,** Bosnia and Herzegovina is **the only Western Balkan country with any forecasted capacity.**

Opportunities

- The current **penetration of intermittent renewables is minimal.**
- Bosnia and Herzegovina stands out as the only **significant electricity exporter** in the Western Balkan region.

Scoring - compared to the 25 EU countries

Overall ranking: bottom 5%

Current challenges and electricity markets ranking: bottom 5%

Challenges in 2030 ranking: top 20%

Opportunities ranking: bottom 20%

Strengths for Grid Transition

- Low number of interruptions
- High exports of electricity

Difficulties for Grid Transition

- Low accuracy of demand forecast
- High imbalance volume
- High deviation of load
- Low demand response capacity in 2030

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted.

Montenegro

(not prepared)

Overview

- Relative to its size, Montenegro leads in **intermittent renewable penetration** within the Western Balkans, a position set to strengthen by 2030.
- Montenegro currently relies on **a mix of coal and hydro** to meet its electricity needs.
- Like other Western Balkan countries, Montenegro's **electricity market indicators lag behind** even the lowest-performing EU countries.

Challenges today and electricity markets

- Electricity **losses are extremely high** even compared to other Western Balkan countries, reaching nearly 20%.
- Despite low performance in other market indicators, Montenegro **performs well in terms of low spot price volatility and the absence of negative prices.**

Challenges in 2030

- The forecasted rollout of **intermittent renewables by 2030 is significantly higher** than in other Western Balkan countries, driven primarily by solar PV growth.
- Although Montenegro is a **strong performer in smart metering,** even compared to the EU, no demand response capacity is forecasted by 2030.

Opportunities

- Montenegro can capitalize on its **extensive interconnectors,** considering the small size of the country.
- The combination of **widespread smart metering and electric heating** presents a potential for **demand response** that is untapped.

Scoring - compared to the 25 EU countries

Overall ranking: bottom 5%

Current challenges and electricity markets ranking: bottom 5%

Challenges in 2030 ranking: bottom 20%

Opportunities ranking: top 20%

Strengths for Grid Transition

- Low spot price volatility
- Low occurrence of negative prices
- Low forecasted inadequacy of capacity in 2030
- High share of smart metering
- High capacity of interconnectors

Difficulties for Grid Transition

- Low accuracy of demand forecast
- High number of interruptions
- High imbalance volume
- High deviation of load
- High peak load
- High grid losses
- No forecasted battery or demand response capacity in 2030

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted.

North Macedonia

(not prepared)

Overview

- North Macedonia primarily generates electricity from **coal, natural gas, and hydro.**
- Coal capacities are **expected to phase-out** by 2030, though this commitment is uncertain due to the ongoing energy crisis.
- The **penetration of intermittent renewables is minimal,** with future expansion projected to align with the Western Balkan average.
- Like other Western Balkan countries, many of North Macedonia's **electricity market indicators fall below** even the lowest-performing EU countries.

Challenges today and electricity markets

- North Macedonia's electricity market performance **is average compared to other Western Balkan** countries.

Challenges in 2030

- North Macedonia shows relatively good results in this category, largely due to its **limited ambitions for intermittent renewables and its extensive hydro capacities.**
- However, **no battery storage or demand response** capacity is forecasted for 2030.
- The phasing out of coal is expected to be offset by **new wind and solar capacities.**

Opportunities

- The penetration of **renewable capacities today is relatively low.**
- The country also **lacks any pumped hydro storage** capabilities.

Scoring - compared to the 25 EU countries

Overall ranking: bottom 5%

Current challenges and electricity markets ranking: bottom 5%

Challenges in 2030 ranking: top 50%

Opportunities ranking: the worst

Strengths for Grid Transition

- Low price volatility
- Low occurrence of negative spot prices
- Low imbalance price

Difficulties for Grid Transition

- Low accuracy of demand forecast
- High number of interruptions
- High imbalance volume
- High deviation of load
- High peak load
- High grid losses
- No forecasted battery or demand response capacity in 2030
- Low penetration of intermittent renewables today

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted.

Serbia

(not prepared)

Overview

- Serbia primarily relies **on coal for electricity generation.**
- Unlike other Western Balkan countries, Serbia's **electricity market performs relatively well,** reaching average EU levels.
- Forecasted **demand growth in Serbia is among the highest** in the Western Balkans, expected to be largely met by an increase in **intermittent renewable generation.**

Challenges today and electricity markets

- Serbia stands out in the region for its **strong performance in imbalance volume management and relatively low peak loads.**
- Although both **load forecast accuracy and interruptions occurrence are below the EU average,** they are notably better than the Western Balkan average.

Challenges in 2030

- **No battery storage or demand response** capacities are projected by 2030.
- Serbia, unlike other Western Balkan countries, **will not be able to rely on substantial hydro capacities** by 2030.

Opportunities

- Serbian low results stem from the **relatively low penetration of renewable energy capacities.**
- The country also has **very low interconnector capacities** compared to both EU and Western Balkan standards.
- Currently, the penetration of **smart metering is negligible.**

Scoring - compared to the 25 EU countries

Overall ranking: bottom 5%

Current challenges and electricity markets ranking: bottom 20%

Challenges in 2030 ranking: bottom 30%

Opportunities ranking: the worst

Strengths for Grid Transition

- Low imbalance volume
- Low occurrence of negative spot prices

Difficulties for Grid Transition

- High reliance on electricity generation from coal
- No forecasted battery or demand response capacity in 2030
- No smart metering
- Low penetration of intermittent renewables today

The content of this factsheet is based on quantitative data analysis from the GLOBSEC Grid Transition Index. Comparative statements reflect normalized data according to the methodology's specified variables, unless otherwise noted.

Bibliography

Bloomberg, 2023. *A Giant Grid Bottleneck Is Threatening Climate Goals*. Available online: https://www.bloomberg.com/news/articles/2023-06-30/why-bigger-better-power-grids-are-needed-to-achieve-climate-goals

Cremona, E., Rosslowe, C., 2024. *Putting the mission in transmission: Grids for Europe's energy transition*. Available online: https://ember-climate.org/insights/research/putting-the-mission-in-transmission-grids-for-europes-energy-transition/#supporting-material

Cremona, E., Rosslowe, C., Pató, Z., 2024. *Transparent Grids for All*. Available online: https://ember-climate.org/insights/commentary/transparent-grids-for-all/

De la Esperanza Mata Pérez, M., Scholten, D., Smith Stegen, D., 2019. The multi-speed energy transition in Europe: Opportunities and challenges for EU energy security, *Energy Strategy Reviews*, 26 (100415). Available online: https://www.sciencedirect.com/science/article/pii/S2211467X19301087

Draghi, M., 2024. *The future of European competitiveness, part B.* Available online: https://commission.europa.eu/document/download/ec1409c1-d4b4-4882-8bdd-3519f86bbb92_en?filename=The%20future%20of%20European%20competitiveness_%20In-depth%20analysis%20and%20recommendations_0.pdf

EC, 2023. *Grids, the missing link - An EU Action Plan for Grids*. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023DC0757

Enterline, S., Valainis, A., 2024. *Laws in Order: An Inventory of State Renewable Energy Siting Policies.* Available online: https://live-lbl-eta-publications.pantheonsite.io/sites/default/files/rap-enterline-valainis-laws-order-inventory-state-renewable-energy-siting-policies-2024-june.pdf

Financial Times, 2023. *Gridlock: how a lack of power lines will delay the age of renewables*. Available online: https://www.ft.com/content/a3be0c1a-15df-4970-810a-8b958608ca0f

IEA, 2023a. *Average lead times to build new electricity grid assets in Europe and the United States, 2010-2021.* Available online: https://www.iea.org/data-and-statistics/charts/average-lead-times-to-build-new-electricity-grid-assets-in-europe-and-the-united-states-2010-2021

IEA, 2023b. *Electricity Grids and Secure Energy Transitions*. Available online: https://iea.blob.core.windows.net/assets/ea2ff609-8180-4312-8de9-494bcf21696d/ElectricityGridsandSecureEnergyTransitions.pdf

IPCC, 2022. *Sixth Assessment Report, Chapter 6: Energy Systems.* Available online: https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter06.pdf

Ofgem, 2023. *Ofgem announces tough new policy to clear 'zombie projects' and cut waiting time for energy grid connection*. Available online: https://www.ofgem.gov.uk/press-release/ofgem-announces-tough-new-policy-clear-zombie-projects-and-cut-waiting-time-energy-grid-connection

Pollitt, M., Covatariu, A. & Duma, D., 2024. *Towards a More Dynamic Regulation for Energy Networks.* Available online: https://cerre.eu/wp-content/uploads/2024/03/CERRE_Dynamic_Regulation_Report_FINAL-1.pdf

SPgroup, 2022. *Smart Grid Index*. Available online: https://www.spgroup.com.sg/our-services/network/overview/smart-grid-index

The Economist, 2023. *Can Europe's power grid cope with the green transition?* Available online: https://www.economist.com/business/2023/09/28/can-europes-power-grid-cope-with-the-green-transition

Wall Street Journal, 2024. *The Coming Electricity Crisis.* Available online: https://www.wsj.com/articles/electric-grid-crisis-biden-administration-climate-policy-energy-artificial-intelligence-cfc10b68

World Energy Council, 2024. *World Energy Trilemma Framework*. Available online: https://www.worldenergy.org/transition-toolkit/world-energy-trilemma-framework

World Economic Forum, Accenture, 2023. *Fostering Effective Energy Transition*. Available online: https://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_2023.pdf

Annex 1: Overview of indicators

Name (unit)	1. and 2. Electricity generation from coal and oil (TWh)
Area	Challenges today and the electricity markets
Year	2022
Ranking	Countries with a higher generation have a lower score
Points (out of 100)	10
Normalization	By national electricity consumption in 2022
Data source	Eurostat
Justification	The energy transition necessitates the phaseout of fossil fuel-based electricity generation. Replacing coal and oil-generated power will place additional strain on electricity grids, as these dispatchable energy sources may need to be substituted with intermittent renewable alternatives.

Name (unit)	3. Electricity generation from natural gas (TWh)
Area	Challenges today and the electricity markets
Year	2022
Ranking	Countries with a higher generation have a lower score
Points (out of 100)	4
Normalization	By national electricity consumption in 2022
Data source	Eurostat
Justification	The energy transition will require phasing out fossil fuel-based electricity generation. Although natural gas is less carbon-intensive than coal or oil, its use is expected to decrease, serving mainly to meet peak demand and provide ancillary services. Removing natural gas-generated electricity will place additional pressure on electricity grids, as this reliable, dispatchable source will need to be substituted.

Name (unit)	4. Absolute imbalance volume (MWh)
Area	Challenges today and the electricity markets
Year	2023
Ranking	States with a higher imbalance have lower scores
Points (out of 100)	5
Normalization	By national electricity consumption in 2022 (TWh)
Data source	ENTSOE
Justification	High imbalance volumes indicate unpredictable fluctuations in both electricity demand and supply, as well as limited flexibility in the grid. As the share of renewables increases, this challenge is expected to intensify, potentially compromising the stability of electricity grids. It's important to note that high imbalance, whether in surplus or deficit, is considered significant. Therefore, imbalance is calculated based on its absolute volume.

Name (unit)	5. Load forecast accuracy (%)
Area	Challenges today and the electricity markets
Year	2023
Ranking	Countries with better load forecast accuracy have higher score

Points (out of 100)	5
Normalization	Per average actual load (MW)
Data source	ENTSOE
Justification	The ability to accurately forecast electricity system load is crucial for enabling greater integration of renewable energy sources and reducing the reliance on ancillary services.

Name (unit)	6. System Average Interruption Frequency Index (SAIFI)
Area	Challenges today and the electricity markets
Year	2019
Ranking	States with a higher SAIFI have lower scores
Points (out of 100)	3
Normalization	-
Data source	World Bank
Justification	SAIFI (System Average Interruption Frequency Index) is a widely used reliability metric for electricity grids, quantifying the average number of power interruptions experienced by a customer per year. High SAIFI levels indicate significant infrastructural challenges and investment gaps faced by TSOs and DSOs. As electricity demand continues to rise and the integration of intermittent renewable energy sources increases, the SAIFI is expected to increase further.

Name (unit)	7. and 8. Transmission and distribution losses (%)
Area	Challenges today and the electricity markets
Year	2022
Ranking	Countries with higher losses have lower scores
Points (out of 100)	3
Normalization	-
Data source	Eurostat
Justification	High transmission and distribution losses can signal several challenges within the grid, such as an investment gap, difficult natural environments, and geographically dispersed loads. These higher losses result in increased costs for consumers and may require additional investments.

Name (unit)	9. Load standard deviation (MW)
Area	Challenges today and the electricity markets
Year	2023
Ranking	Countries with higher load standard deviation have lower scores
Points (out of 100)	2
Normalization	Per average actual load (MW)
Data source	ENTSOE
Justification	Higher standard deviations in load indicate greater fluctuations in electricity demand. This variability can increase the need for ancillary services and necessitate rapid adjustments in production levels, often requiring fossil fuel sources. Consequently, this leads to higher costs for the electricity grid.

Name (unit)	10. Peak load (MW)
Area	Challenges today and the electricity markets
Year	2023
Ranking	Countries with higher load standard deviation have lower scores
Points (out of 100)	2
Normalization	Per average actual load (MW)
Data source	ENTSOE
Justification	Peak loads create a significant strain on the electricity system, impacting not only generation but also transmission. Large deviations between peak loads and average loads indicate greater stress on the system and generally necessitate increased infrastructural investments.

Name (unit)	11. Day-ahead price volatility
Area	Challenges today and the electricity markets
Year	2023
Ranking	States with a higher volatility have a lower score
Points (out of 100)	6
Normalization	None
Data source	ENTSOE
Justification	High price volatility, as measured by standard deviation, indicates a lack of flexibility in electricity systems among generators and/or limited load-shifting capabilities among electricity consumers. The further decarbonization and increased adoption of intermittent renewables are likely to exacerbate this issue.

Name (unit)	12. Negative day-ahead prices (%)
Area	Challenges today and the electricity markets
Year	2023
Ranking	States with a higher occurrence of low prices have a lower score
Points (out of 100)	6
Normalization	None
Data source	ENTSOE
Justification	While low electricity prices may initially benefit consumers, regular occurrences of negative prices can adversely affect the business viability of new electricity generators, thereby discouraging further investments in the sector over the long term. Additionally, negative prices may also indicate a lack of grid flexibility and potentially flawed incentives, such as through feed-in tariffs.

Name (unit)	13. Average imbalance price (€/MWh)
Area	Challenges today and the electricity markets
Year	2023
Ranking	States with a higher imbalance price have lower scores
Points (out of 100)	4
Normalization	None
Data source	ENTSOE

Justification	High imbalance prices signify a lack of grid flexibility and high costs associated with ancillary services, which are expected to escalate with ongoing decarbonization efforts. Both very high and very low imbalance prices indicate insufficient flexibility within the grid. Given this, imbalance prices are calculated with absolute terms due to their negative impact regardless of whether they are exceptionally high or low.

Name (unit)	14. Growth of intermittent renewables generation 2022-2030 (TWh)
Area	Challenges in 2030
Year	2030
Ranking	Countries with higher growth have lower scores
Points (out of 100)	3
Normalization	By national electricity consumption in 2022 (TWh)
Data source	National Energy and Climate Plans, Ember, ERAAs
Justification	Individual countries outline their projected electricity mix for 2030 in their National Energy and Climate Plans (NECPs). As part of transitioning away from fossil fuel generation, many of these plans rely heavily on intermittent renewables, primarily solar and wind energy. While this is a sensible strategy for the green transition, the high volume of intermittent energy will place significant stress on grids, requiring additional interconnectors, energy storage, and grid flexibility. Indicator tracks the energy produced from new renewable sources. Existing intermittent renewable sources (2022) are excluded from this indicator since their generation is already integrated and reflected in financial fundamentals. The indicator is normalized by electricity consumption to account for the size of each country and its capacity to integrate new renewable energy sources.

Name (unit)	15. Growth of intermittent renewables capacity 2022-2030 (GW)
Area	Challenges in 2030
Year	2030
Ranking	Countries with higher growth have lower scores
Points (out of 100)	7
Normalization	By national electricity consumption in 2022 (TWh)
Data source	National Energy and Climate Plans, Ember, ERAAs
Justification	Individual countries outline their projected electricity mix for 2030 in their National Energy and Climate Plans (NECPs). As part of transitioning away from fossil fuel generation, many of these plans rely heavily on intermittent renewables, primarily solar and wind energy. While this is a sensible strategy for the green transition, the high volume of intermittent energy will place significant stress on grids, requiring additional interconnectors, energy storage, and grid flexibility. The indicator tracks the capacity of new renewable sources. The weight given is higher than in the case of renewable energy produced because the grids will be mostly negatively influenced by large influx of generation from renewables at any one point, for which capacity is a better proxy. Existing intermittent renewable sources (2022) are excluded from this indicator since their generation is already integrated and reflected in financial fundamentals. The indicator is normalized by electricity consumption to account for the size of each country and its capacity to integrate new renewable energy sources.

Name (unit)	16. Growth of demand (TWh)

Area	Challenges in 2030
Year	2030
Ranking	Countries with higher growth have lower scores
Points (out of 100)	3
Normalization	By national electricity consumption in 2022 (TWh)
Data source	European Resource Adequacy Assessments (ERAAs) from 2024
Justification	Every TSO regularly publishes an ERAA, which includes demand forecasts for 2030. The significance of rising demand is that electricity systems will need to cover not only the existing needs currently met by fossil fuels but also new demands arising from the electrification of industry, transport, and heating, increased wealth, and the growth of sectors such as artificial intelligence.

Name (unit)	17. Capacity of batteries (MW)
Area	Challenges in 2030
Year	2030
Ranking	Countries with higher capacity of batteries have higher scores
Points (out of 100)	3
Normalization	By national electricity consumption in 2030 (TWh)
Data source	European Resource Adequacy Assessments (ERAAs) from 2024
Justification	Every TSO regularly publishes an ERAA, which includes forecasts for battery capacity in the electricity system by 2030. Batteries play a crucial role in stabilizing the grid, providing ancillary services, and facilitating the integration of intermittent renewable energy sources. The scoring of battery, demand response, and hydro capacities reflects the relative importance of these technologies, as reported by ERAAs at the national level.

Name (unit)	18. Capacity of demand response (MW)
Area	Challenges in 2030
Year	2030
Ranking	Countries with higher capacity of demand response have higher scores
Points (out of 100)	1
Normalization	By national electricity consumption in 2030 (TWh)
Data source	European Resource Adequacy Assessments (ERAAs) from 2024
Justification	Every TSO regularly publishes an ERAA, which includes forecasts for demand response capacity in 2030. Demand response is a cost-effective tool that can significantly facilitate the integration of intermittent renewable energy sources. The scoring of battery, demand response, and hydro capacities reflects the relative importance of these technologies, as reported by ERAAs at the national level.

Name (unit)	19. Reservoir and pondage hydro (MW)
Area	Challenges in 2030
Year	2030
Ranking	Countries with higher capacity of demand response have higher scores
Points (out of 100)	3
Normalization	By national electricity consumption in 2030 (TWh)

Data source	European Resource Adequacy Assessments (ERAAs) from 2024
Justification	Every TSO regularly publishes an ERAA, which includes forecasts for reservoir and pondage hydro capacity in 2030. Hydro storage is a cost-effective tool that can significantly facilitate the integration of intermittent renewable energy sources. The scoring of battery, demand response, and hydro capacities reflects the relative importance of these technologies, as reported by ERAAs at the national level.

Name (unit)	20. Reservoir and pondage hydro (MW)
Area	Challenges in 2030
Year	2030
Ranking	Countries with higher capacity of demand response have higher scores
Points (out of 100)	3
Normalization	By national electricity consumption in 2030 (TWh)
Data source	European Resource Adequacy Assessments (ERAAs) from 2024
Justification	Every TSO regularly publishes an ERAA, which includes forecasts for reservoir and pondage hydro capacity in 2030. Pumped hydro storage is a cost-effective tool that can significantly facilitate the integration of intermittent renewable energy sources. The scoring of battery, demand response, and hydro capacities reflects the relative importance of these technologies, as reported by ERAAs at the national level.

Name (unit)	21. Loss Of Load Expectation - LOLE (h/year)
Area	Challenges in 2030
Year	2030
Ranking	States with a higher LOLE have a lower score
Points (out of 100)	2
Normalization	None
Data source	National European Resource Adequacy Assessments (2023)
Justification	Transmission System Operators (TSOs) regularly assess the adequacy of their grids for short- and mid-term periods. In these evaluations, they estimate the Loss of Load Expectation (LOLE) metric for a central scenario in 2030. LOLE represents the number of hours per year in which the electricity system is expected to be unable to meet demand. High levels of LOLE indicate that TSOs will need to implement additional mechanisms, such as capacity mechanisms and interconnectors investments, to ensure grid stability.

Name (unit)	22. Generation of intermittent renewables today (TWh)
Area	Opportunities
Year	2022
Ranking	States with a higher generation of intermittent renewables have higher scores
Points (out of 100)	10
Normalization	By national electricity consumption in 2022 (TWh)
Data source	Eurostat
Justification	High integration of renewables in today's electricity grids enhances the likelihood of further successful integration in the future. This is attributed to increased experience with intermittent renewables among investors, public institutions, and, most importantly, DSOs and TSOs.

Name (unit)	23. Cross-border transmission capacity (MW)
Area	Opportunities
Year	2024
Ranking	States with a higher forecasted transfer capacities (year ahead) have higher scores
Points (out of 100)	3
Normalization	Average load (MW)
Data source	ENTSOE and Amber
Justification	High transmission capacity enhances the likelihood of a successful grid transition by improving the ability to export excess generation and import energy when needed. Additionally, greater interconnectedness helps overcome some of the natural limitations of intermittent renewables, such as local meteorological conditions.

Name (unit)	24. Electricity net import (TWh)
Area	Opportunities
Year	2022
Ranking	States with a higher share of net imports have lower scores
Points (out of 100)	2
Normalization	By national electricity consumption in 2022 (TWh)
Data source	Eurostat
Justification	Countries with high net electricity imports rely on neighbouring countries to meet their electricity needs. Conversely, countries with net exports are more resilient to unexpected shocks, as their generation exceeds their own consumption.

Name (unit)	25. Pumped hydro today (TWh)
Area	Opportunities
Year	2022
Ranking	States with a higher usage of pumped hydro have higher scores
Points (out of 100)	3
Normalization	By national electricity consumption in 2022 (TWh)
Data source	Eurostat
Justification	Pumped hydro storage significantly enhances grid flexibility and enables cost-effective demand-shifting. While pumped hydro potential may already be depleted, existing installations can be repowered and their capacity expanded to further leverage this technology.

Name (unit)	26. Share of household consumers with smart meters (%)
Area	Opportunities
Year	2022
Ranking	States with a higher share of households with smart meters have higher scores
Points (out of 100)	3
Normalization	-
Data source	ACER
Justification	A higher rate of smart metering enhances grid stability by providing abundant data and encouraging energy savings and demand shifting among consumers. Additionally, a high adoption rate indicates a greater uptake of innovative technologies within the utility sector.

Name (unit)	27. Share of electricity consumption for space and water heating (%)
Area	Opportunities
Year	2022
Ranking	States with a higher share of electricity consumption for space and water heating have higher scores
Points (out of 100)	1
Normalization	Out of all energy use for space and water heating (TWh)
Data source	Eurostat
Justification	Electrifying residential heating is a crucial step in the green transition and represents the most cost-effective pathway for achieving decarbonization goals in the building sector. However, this transition will necessitate investments in grid infrastructure due to the strong interdependence of this load type with external weather conditions and thus with each other. The widespread adoption of electric heating today, particularly through heat pumps, indicates that the countries are already successfully integrating this type of load and/or their geographic conditions are enabling to heat electrification.

Name (unit)	28.-29. Funding earmarked for the grid investments in Recovery and Resilience Facilities (RRFs)
Area	Opportunities
Year	2022
Ranking	States with funding earmarked for grids in their RRFs have higher scores
Points (out of 100)	2
Normalization	-
Data source	European Commission
Justification	Grid transitions will necessitate widespread investments in infrastructure. While these investments could theoretically be funded by increased tariffs for consumers, such an approach would raise electricity costs and potentially slow the transition to low-carbon energy sources. Therefore, public funding may be a viable alternative to improve the likelihood of a successful grid transition. The indicator tracks national Recovery and Resilience Facilities (RRFs) and the presence of earmarked funding for grids as a proxy for broader public financing of grid transitions. Specifically, it monitors funding for general grid infrastructure and grid-level energy storage, with both given equal weight. The indicator only considers the presence or absence of funding, without accounting for the size of the funding due to insufficient data.

Name (unit)	30. Legislation reform connected to grids in Recovery and Resilience Facilities (RRFs)
Area	Opportunities
Year	2022
Ranking	States with legislation reform in their RRFs have higher scores
Points (out of 100)	1
Normalization	-
Data source	European Commission
Justification	Grid transitions will require legislative reforms to facilitate the quicker rollout of grid infrastructure. The inclusion of such reforms in national Recovery and Resilience Facilities (RRFs) indicates a higher level of political commitment to these issues. The indicator tracks national RRFs to identify countries that have undertaken legislative reforms related to electricity grids. It measures only the presence or absence of these reforms, without conducting a qualitative assessment.

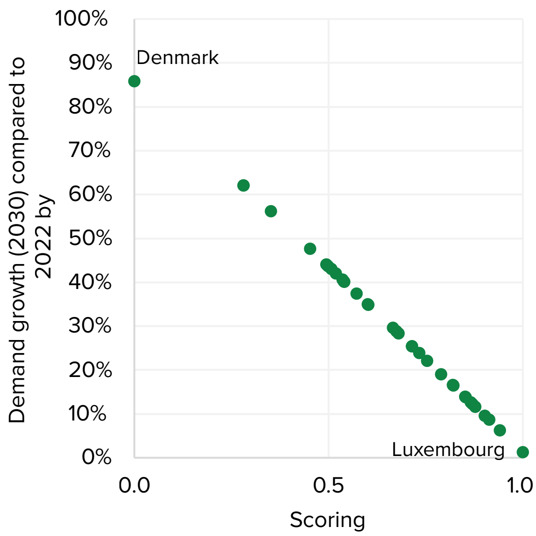
Annex 2: Scoring

The scoring system follows a straightforward linear approach. The EU country with the lowest performance is assigned 0 points, while the country with the highest performance is awarded 1 point, weighted according to the indicator's importance. As illustrated in Figure 9, Denmark in this indicator represents the highest performer, while Luxembourg ranks lowest. The scores for other countries are calculated proportionally, reflecting their performance relative to these two benchmarks. Non-EU countries performing below the weakest EU country receive 0 points, and those surpassing the top-performing EU country receive 1 point.

For extreme outliers, an adjusted method is applied. When a significant gap exists, the outlier country is assigned either 0 or 1 point, with the remaining countries' scores starting from 0.2 or 0.8 points, as illustrated in Figure 10.

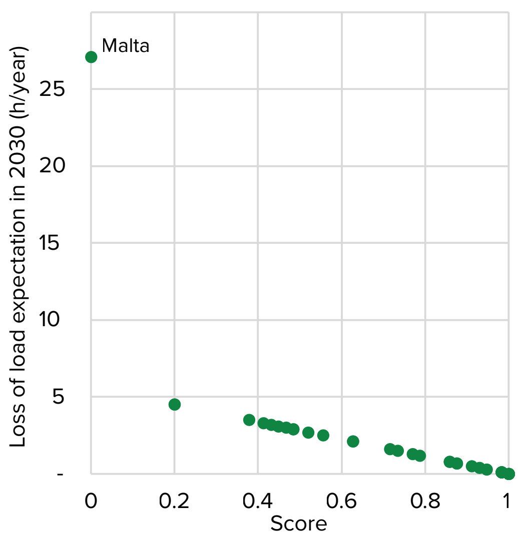
The scores are consequently multiplied by weights given to individual indicators.

Figure 9: Scoring without outliers



Source: GLOBSEC

Figure 10: Scoring with an outlier



Source: GLOBSEC

Annex 3: Numerical results

	Current challenges and elec. markets	Challenges in 2030	Opportunities	Result
Spain	39.7	14.9	16.9	highly prepared
Luxembourg	39.4	17.1	10.6	highly prepared
Portugal	35.0	14.3	14.3	highly prepared
Austria	35.5	16.6	9.2	highly prepared
Sweden	36.6	11.6	12.6	highly prepared
France	36.9	13.8	8.8	highly prepared
Belgium	36.4	12.7	9.2	moderately prepared
Italy	34.5	14.8	8.4	moderately prepared
Latvia	33.2	14.9	9.0	moderately prepared
Slovakia	35.2	15.0	6.5	moderately prepared
Slovenia	33.7	16.1	6.1	moderately prepared
Croatia	32.2	14.9	8.5	moderately prepared
Finland	33.6	12.8	8.8	moderately prepared
Greece	26.8	15.5	11.9	partially prepared
Denmark	33.2	3.8	16.9	partially prepared
Ireland	32.3	9.9	10.9	partially prepared
Germany	30.6	12.5	9.6	partially prepared
Czechia	31.4	14.8	6.0	partially prepared
Hungary	32.9	11.0	7.2	partially prepared
Romania	27.5	13.1	9.1	not prepared
Poland	27.4	12.7	8.7	not prepared
Bulgaria	22.6	16.8	7.1	not prepared
Lithuania	30.2	7.4	8.4	not prepared
Netherlands	25.5	7.4	12.4	not prepared
Estonia	16.2	9.0	11.0	not prepared
Switzerland	41.8	20.8	10.0	highly prepared
Norway	33.6	20.6	11.9	highly prepared
United Kingdom	33.2	15.7	12.3	highly prepared
Albania	25.7	17.0	4.8	not prepared
Serbia	26.6	11.0	5.1	not prepared
Montenegro	20.6	9.7	12.0	not prepared
N. Macedonia	22.1	13.2	5.3	not prepared
Bos. and Herz.	17.1	16.2	6.7	not prepared
Malta*				not prepared
Cyprus*				not prepared
Max. points	**50**	**25**	**25**	

** Due to the significant number of missing indicators for these countries, they cannot be comprehensively compared to the other countries within individual categories. Instead, only basic comparisons based on all available data were conducted.*

Notes

GLOBSEC
IDEAS SHAPING THE WORLD

Vajnorská 100/B
831 04 Bratislava
Slovak Republic

+421 2 3213 7800
info@globsec.org
www.globsec.org