Grid access challenges for wind farms in Europe

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Executive summary

As things stand, securing access to the electricity grid is the number one bottleneck to deploying renewables at scale.

Grid access starts with grid connection. Currently more than 500 GW of total wind capacity in Croatia, France, Germany, Ireland, Italy, Norway, Poland, Romania, Spain and the UK are waiting for grid connection assessment. The total stand-by capacity figure for Europe is much higher. This is not just due to grid saturation or lack of adequate planning up to 2050. Grid permitting procedures are also inefficient.

Curtailment is the second key factor limiting grid access to renewable generation. Wind farms may be connected to the grid but cannot export a large part of their generation due to grid congestion - a problem which can last for several hours. Across Europe there is very little transparency when it comes to annually curtailed renewable energy volumes and congestion costs. Very few national authorities have published this sort of important data that could justify proactive grid planning or accelerated grid investments.

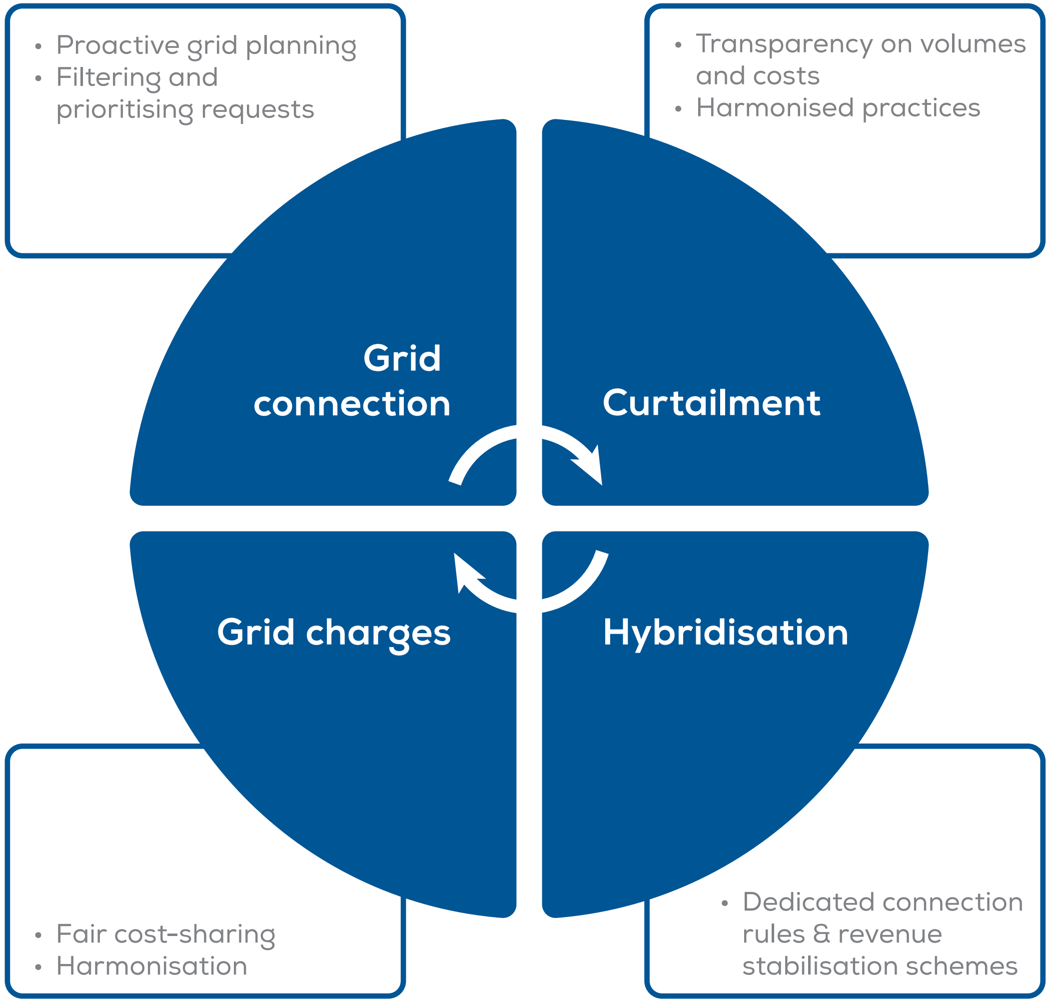
If National Governments take targeted action to accelerate grid connectivity - and guarantee a balanced allocation of grid capacity to all strategic net-zero technologies, Europe will make major progress toward its climate goals.

To better understand the different grid permitting and curtailment practices across Europe, WindEurope launched a survey in October 2023 to gather information from stakeholders at national level. This report lays out the findings from the survey. The scope covers four areas: grid connection, grid charges, curtailment and hybridisation. It also highlights areas for improvement and processes which national policymakers can employ to accelerate and maximise grid access for wind farms. Here is an outline of what needs to be targeted:

- **Efficient anticipatory planning of transmission and distribution grids.** This should account for new electrified demand and renewable capacity more than 10 years ahead.
- **Moving away from the *first come, first served* principle** for granting grid access to new generation and demand. This principle has led to an unbalanced mix of technologies in certain areas and suboptimal use of the available grid capacity. Instead, National Governments should apply:
  - **Smart and dynamic management of grid connection queues** with adequate entry criteria, filtering and prioritisation practices.
  - **Strategies to guarantee balanced grid access for all strategic net-zero technologies**.
- **Accelerated implementation of EU legislation** such as the revised Renewable Energy Directive (RED III) and the EU Emergency Permitting Regulation. This would mitigate grid access issues and make grid permitting more efficient both at the transmission and distribution level.
- **Transparent harmonised rules and practices for congestion management, curtailment compensation and flexible (non-firm) grid connection agreements.** The latter should be time-limited and voluntary for generators. To avoid market fragmentation and to ensure a level playing-field among Member States, EU guidance will be vital in implementing relevant obligations in the Electricity Market Design reform and the Network Code Demand Response. **In half of the surveyed countries wind energy curtailment is not compensated - even though this is mandatory under EU law.**
- **A fair sharing of grid expansion and reinforcement costs between generation asset developers and System Operators**. Also setting up frameworks for generation asset developers to develop the grid and hand it over to System Operators upon remuneration.
- **Enabling grid connection rules for co-located renewables with and without storage** (hybridisation) and fit for purpose revenue stabilisation schemes.

This report gives examples of inefficiencies as well as best-practice across Europe - and gives recommendations to national authorities. Figure 1 lays out the four scope areas of the report and the processes that would significantly benefit from guidance at EU level.

FIGURE 1. Focus areas to improve grid access for wind farms



Source: WindEurope

Introduction

As it currently stands grid access is the biggest bottleneck for deploying renewable energy at scale. Grid access starts with grid connection. A critical and challenging part of the permitting process for new or repowered wind farms is in obtaining the grid connection permit. This can take up to 9 years in some countries.

Today more than 500 GW of total wind capacity in Croatia, France, Ireland, Italy, Norway, Romania, Spain and the UK are waiting for their grid connection assessment. The total capacity figure for Europe is much higher. This is not just due to saturation of the grid, or a lack of grid planning up to 2050. Grid permitting procedures are also inefficient.

If National Governments take targeted action to accelerate grid connectivity - and evenly guarantee grid capacity for all strategic net-zero technologies, Europe will make major progress toward its climate goals.

Curtailment is the second major factor limiting grid access for renewable generation. Wind farms may be connected to the grid but unable – often during several hours – to export large shares of their generation due to grid congestion.

Grid congestion in most cases stems from insufficient grid capacity. But an unbalanced mix of renewable generation technologies connected in the same area can also severely intensify grid congestion. Attributing grid capacity using the *first come, first served* grid permitting approach - without considering the specifics of each technology and their permitting lead times - could produce an unbalanced generation mix.

As a result curtailment is growing right across Europe and has become a major uncertainty factor for investments in new renewable capacity. Some countries apply curtailment compensation but not in a harmonised manner. Europe will need targeted mechanisms and regulatory adjustments to address curtailment cost-effectively. It would need to be done in a way that maximises social welfare - including through reductions in CO_2 emissions.

To better understand the different grid permitting and curtailment practices across Europe, WindEurope launched a survey in October 2023 to gather information from stakeholders at a national level. Several companies and national wind energy associations have made a significant contribution - and have been acknowledged at the start of this report. Our aim is to summarise the findings of this survey, and to recommend processes that national policymakers can use to improve grid access for wind farms. The report analyses feedback from Belgium, Croatia, Estonia, Germany, Greece, France, Finland, Ireland, Italy, Norway, Poland, Romania, Spain, Sweden and the UK.

1.

Planning and development for new connections

1.1 Overview

To secure a grid permit, asset developers typically use a similar procedure across Europe for new and repowered renewable generation projects. In most cases the key steps involve:

- an initial request to the connecting System Operator for a **preliminary grid access study**;
- **a formal grid connection request** supported by other permitting documents;
- **a detailed techno-economic evaluation** by the System Operator;
- **a detailed technical grid connection plan** by the asset developer; and
- establishment of the **grid connection agreement**.

Section "1.2 The process for attaining grid connection permits" looks into the listed steps, and Section "1.3 Grid connection delays and current backlogs" outlines the key causes of grid connection delays for new renewable generation projects.

In some cases, this accumulated generation capacity will remain on stand-by for several months or even years.

This holds developers back from completing the entire permitting process or developing their assets in general.

This may not only impact the finance and business case of these assets including their supply chain agreements but also new generation capacity that will be progressively adding to the waiting lists.

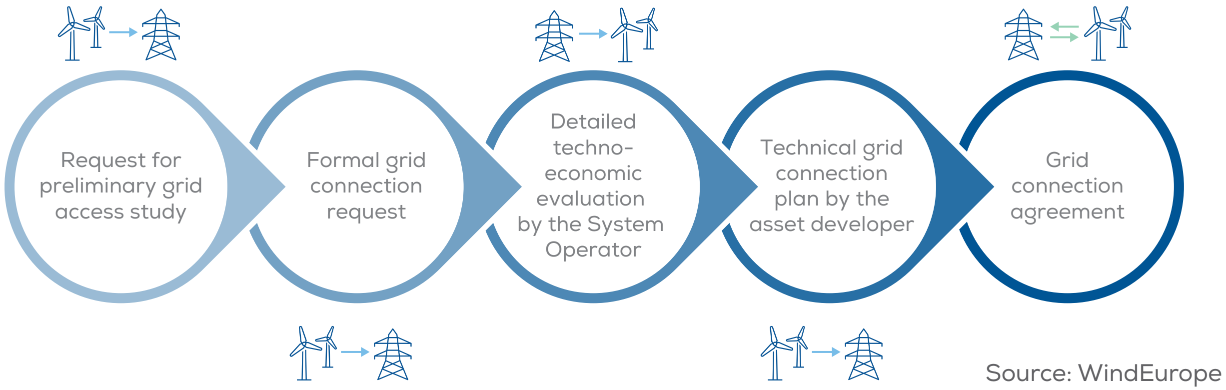
The good news is that some countries have already started discussing or introducing measures to manage grid connection queues more efficiently. Section "1.4 Strategies to improve connection queue management" looks at examples of this.

National wind energy associations consider intervention by national authorities necessary to strengthen procedures for grid connection permitting. Section "1.5 Recommendations to improve grid connection processes" draws conclusions on how some processes could be managed more effectively based on the feedback in the survey.

1.2 The process for attaining a grid connection permit

Figure 2 outlines the main chronological steps that renewable asset developers need to take to secure a grid connection permit. In most cases these processes are clearly laid out by national authorities through online public platforms.

FIGURE 2. The typical steps in the grid connection process across Europe



Request for Preliminary Grid Access Study[1]

The asset developer must initially apply for a preliminary assessment by the relevant System Operator. The latter will indicate potential grid connection points - for instance specific substations and the maximum possible connection power for the particular asset. This is carried out before the System Operator makes a detailed analysis of the technical conditions in the network that may call for grid reinforcements – in case the asset formally submits a grid connection request.

The UK uses a specific digital tool for the initial grid permitting phase - laying out connection timeframes and potential sites for size or connection type. In other countries such as Belgium, the System Operator can already give an initial connection quotation to the developer. This is very useful in planning assets and their finance. The preliminary grid access study does not guarantee a grid connection for the developer. But it may be needed to secure approval elsewhere further along in the permitting process.

This is the case in countries such as Croatia - when the developer is seeking approval for energy production. In Spain the preliminary grid access study is needed for new projects to launch their overall permitting application. In Greece, developers need the initial grid access study to take part in a national wind energy auction and to get a final installation license allowing them to build the wind farm. In Belgium and Sweden this initial grid access assessment takes place together with other permitting procedures.

The information that the asset developer needs to submit at this stage varies from country to country. It usually includes the plans of the asset and the requested connection power. But it might also include site approval documents and other technical descriptions or approvals.

Formal grid connection request

After approval in the first round, asset developers can then submit the formal grid connection request. Typically the System Operator designates in the initial preliminary study the specific substations suitable for connecting the asset. In most cases there is no publicly available or regularly updated network map showing the available capacity at each substation. In countries with high grid saturation up-to-date maps could help asset developers to choose their asset location - based on the grid connection potential as well as the wind resource.

System Operators update their Network Development Plans (NDPs) every few years. But the NDPs are sometimes not reliable when it comes to available grid connection capacities in some regions.

To submit a formal grid connection request in some countries, asset developers need to demonstrate the maturity of their asset with other permitting documents such as the Environmental Impact Assessment, the location concession or others. These extra permitting documents can also sometimes be submitted later - by a specific deadline - once the grid connection permit has been granted. This arrangement can be helpful but only if it is monitored effectively. For instance, it shouldn't lead to grid capacity being blocked for projects that have not been properly evaluated at the time of the connection request.

There are also countries where grid connection requests can only be made during certain periods in a year. In Ireland asset developers can only submit requests once a year based on the existing Enduring Connection Policy. The recent Irish Future Connection Policy Consultation has recommended extending this to two windows per year. This is not helpful given that the general permitting process can be very complex depending on different elements and approvals. A short time on stand-by caused by a delay in the process or a missed time window can bring significant delays in other processes. Being able to apply for grid connections all year round is the best option - and applied in many different countries.

Formal grid connection requests in most countries end up in the same waiting list for all technologies and are treated by the System Operator on a *first come, first served* basis. In most cases the same list applies for generation, storage and consumption.

Detailed techno-economic evaluation by the System Operator

At this stage the System Operator performs detailed technical analysis for the connection of the new asset. This means analysing the existing and future state of the network - including connected users. The System Operator can then formally estimate the available grid capacity, suggest a specific connection point, quantify total costs for the connection - including necessary grid reinforcements beyond the connection point, and formally suggest a connection charge to the developer.

Detailed technical grid connection plan by the asset developer

Once the detailed techno-economic evaluation has been done by the System Operator, the developer needs to look at the proposed grid connection point and connection

1. This preliminary grid access study is defined using different terms across Europe - for instance, in Belgium it is called an "Orientation study".

charge. Should the developer agree with the suggestion, they need to provide a technical assessment and a grid connection plan outlining the technical aspects of connecting their asset. The System Operator will assess and sign-off on the connection plan based on its adherence to regulations and the technical conditions at the proposed connection point.

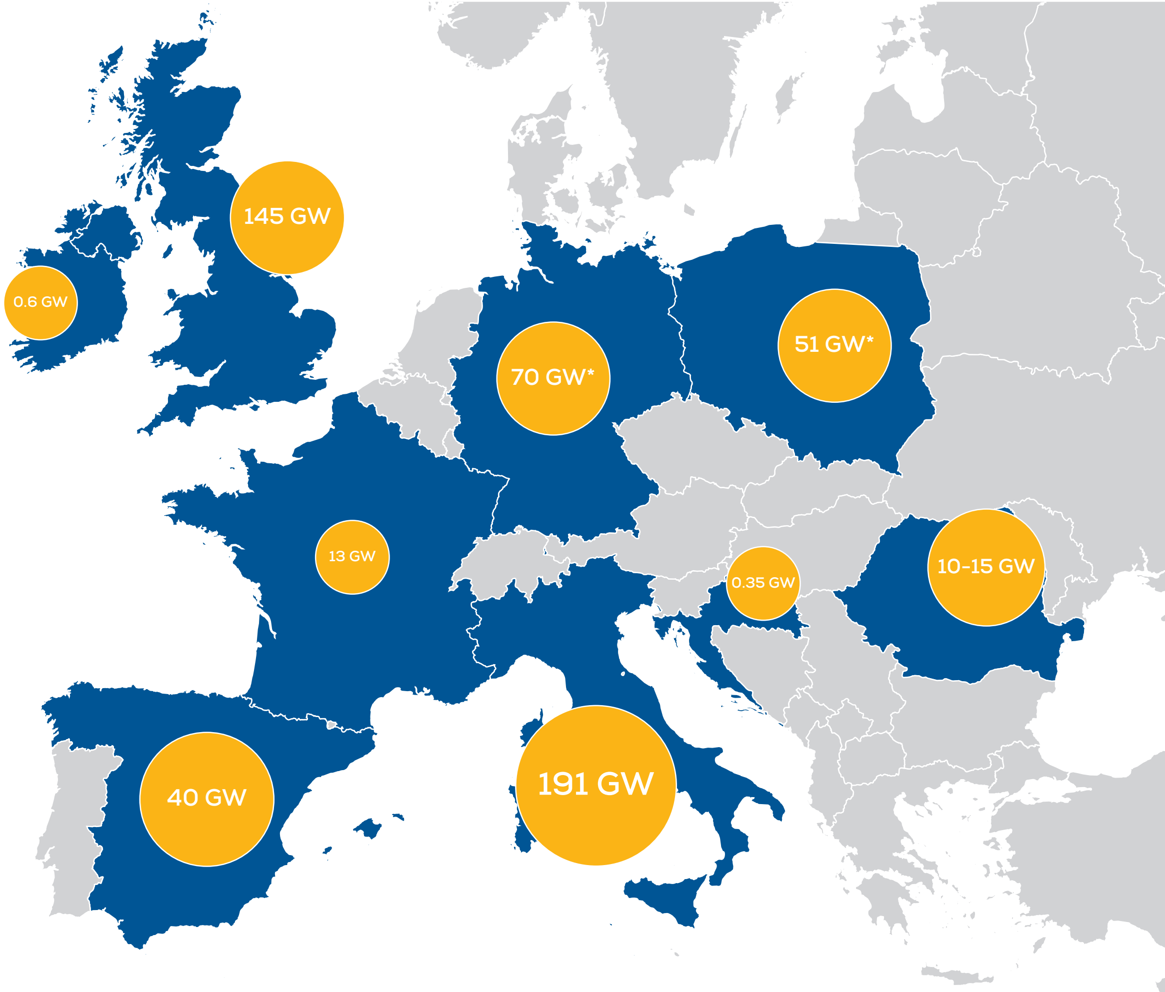
Grid connection agreement

In the final stage, a grid connection agreement is finalised based on the suggestions developed beforehand. This agreement outlines the work needed to set up and install the connection, potential enhancements to the electrical network leading to the connection point, obligations for both parties, detailed tariff components, payment terms, conditions for providing a financial guarantee if required, and conditions for contract termination[2]. In some cases such as in Greece, they also need to secure approval for the land the new substation or high-voltage line is built on.

1.3 Grid connection delays and current backlogs

Across Europe there is a substantial backlog of wind farms waiting for their grid connection assessment. Figure 3 gives an overview of the total wind energy capacity formally included in the grid connection queue.

FIGURE 3. Total wind energy capacity on the waiting list for grid connection assessment[3]



Source: WindEurope, Aurora Energy Research

2. In many cases a default grid connection agreement template is available on the TSO's public website e.g. this is the one offered by Elia in Belgium and this is the one offered by IPTO in Greece.
3. Most data have been provided by national wind energy associations based on publicly available information in Q2 2024. The total capacities in the waiting list might have been slightly updated since the creation of this map. Aurora Energy Research has provided the data about Germany (based on an estimate) and Poland in their publication "Charging ahead: the grid challenge in Europe's pursuit of Net Zero " in March 2024. Data about Germany and Poland refer to all renewable energy capacity and not only wind energy.

Grid saturation challenges

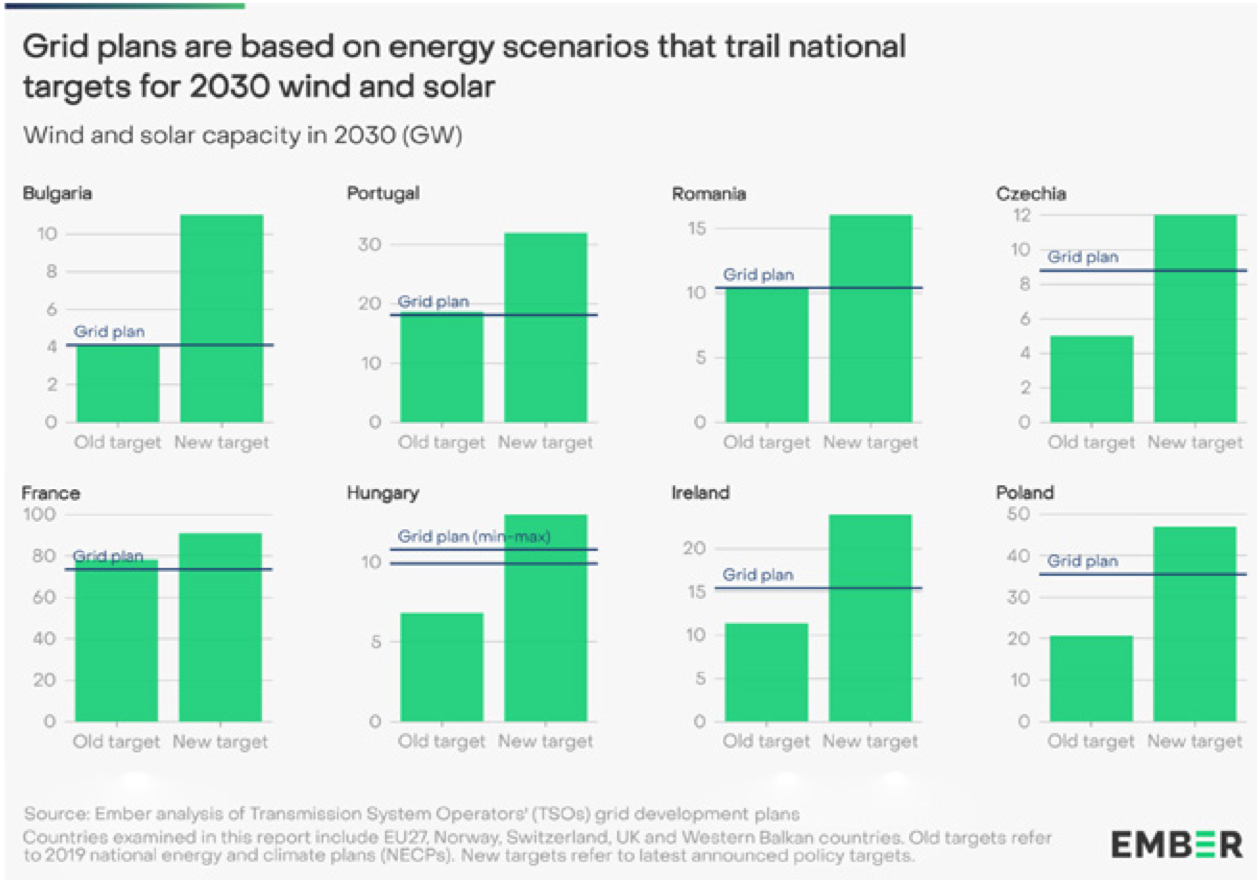
Saturated electricity grids are fast becoming the biggest obstacle to accelerated renewable energy uptake across Europe. In these countries the current grid capacity simply cannot handle new renewable energy and there is a pressing need for grid expansion or modernisation.

In France for example, most grid connection delays are due to the slow construction of high-voltage substations in different regions. In Croatia delays stem from the need to construct a new 400 kV line between Dalmatia and the rest of the country. In Greece the permitting of large volumes of solar PV projects has led to an unbalanced generation mix being connected to the grid and suboptimal use of available grid capacity. Even though the grid capacity could accommodate a more balanced mix of wind and solar, high solar production during sunny hours prevents more wind farms from being integrated. This has also become an issue in France, Romania and Spain.

But grid saturation is also made worse by slow or inefficient grid planning, decision-making for grid investments, and the slow deployment of consented grid expansions and reinforcements. A number of factors undermine these processes.

National authorities and System Operators often fail to engage in proactive planning for grid expansions and reinforcements. It is vital that national grids are capable of integrating the new volumes of renewable energy foreseen under the National Energy and Climate Plans (NECPs). Figure 4 shows that in some European countries the national NDPs do not align with national renewable energy targets.

FIGURE 4. Lack of alignment between national wind and solar capacity targets and grid plans



Source: EMBER[4]

4. EMBER, "Grids for Europe's energy transition report", 2024

Another issue is the method of calculating the grid's hosting capacity to integrate new renewables. Overly conservative "worst-case" scenarios or unrealistic simplifications[5] can lead to pessimistic hosting capacity estimations, holding up grid connection queues for a long time.

These conservative calculations can sometimes overestimate the grid reinforcements needed to host new renewables. This leads to unreasonable grid connection charges that new asset developers are expected to shoulder. This sort of situation is currently being seen in Croatia. These exaggerated connection costs can significantly undermine the viability of new renewable energy projects.

At the same time in most countries incentives for System Operators to minimise the duration of the grid connection process do not go far enough. And in most cases there is no public or adequately updated information on grid saturation per area – taking reserved capacity into account as well. In countries with heavily saturated electricity grids, this sort of information could push asset developers towards less saturated areas.

In Greece, Finland, France, Italy, and the UK third parties such as wind farm developers can undertake the grid work needed to fast-track the process if the System Operator cannot expand or reinforce the grid quickly on its own. But in most cases, this does not apply at all voltage levels. The developer pays for the work in advance and in some cases gets reimbursed by the System Operator afterwards - or shares the costs with other developers connecting their assets in the same area.

Finally, System Operators are often insufficiently incentivised to apply uniform EU standards in technical grid connection assessments and network code compliance. This can often lead to inefficient authorisation processes contingent on project-specific factors.

Procedural inefficiencies

Procedural inefficiencies can worsen grid saturation issues. These inefficiencies also vary among countries. **In most cases the grid permitting process is linked to other authorisations as part of the permitting procedure for a given asset. In theory these strategies are very efficient for prioritising grid capacity for generally mature and viable projects. But in many countries such as Belgium, Germany, Finland, Ireland, Norway and Romania the other authorisations might be handled ineffectively by the respective authorities. As a result they may end up slowing down or blocking the grid permitting process too.** So it is clear that this area needs more scrutiny.

But in many cases also the grid permitting process itself is not managed properly by the relevant authorities due to human resource shortages, a lack of digitalisation, poor planning, a lack of incentives or liabilities that could spur improvement.

And if the time window for connection requests is short, many developers end up on a lengthy standby in case they miss out. In Ireland asset developers only have a single batch of two months a year to apply for a grid connection.

Furthermore, as it stands the *first come, first served* principle applies in most countries when grid connection requests are assessed. But the waiting lists often include many projects that are speculative and will not be deployed. Still the System Operator is obliged by law to assess them - blocking for long periods other projects further along in the queue that are viable and mature.

In Italy and Turkey the entry criteria for the waiting list are too generous - and not effective at keeping out speculative projects. But very few national authorities and System Operators have begun applying smart dynamic management practices as discussed in Section 1.4. This could help to prioritise the most mature projects or projects that bring strategic benefits - in terms of system integration or other factors. And it could also guarantee a balanced allocation of grid capacity for all strategic technologies.

Finally, System Operators also need to go through long public procurement processes for grid equipment, which can delay things further. This is the case in Romania and Sweden for example.

Figure 5 looks at the major factors which delay the connection of renewable assets to Europe's electricity grid. Table 1 shows those countries where the delaying factors apply, according to the survey results.

5. Considering for instance that all wind and solar PV assets constantly produce their maximum power output.

FIGURE 5. Major factors delaying wind farms from getting grid connected

GRID SATURATION

- A lack of available grid capacity
- No proactive grid planning
- Conservative hosting capacity calculation
- Not enough incentives to accelerate grid planning and optimisation
- No useful mapping of grid saturated areas

PROCEDURAL INEFFICIENCIES

- Grid permitting not efficiently linked to other permitting processes
- First come first served principle
- Not strict enough criteria to enter the connection queue
- Shortage of human resources and digitalisation
- Not enough incentives to accelerate the assessment

Source: WindEurope

TABLE 1. Application of grid connection delaying factors across Europe

	Delaying Factors	Countries
Grid Saturation	**A lack of available grid capacity**	Croatia, Finland, France, Germany, Greece, Italy, Ireland, Netherlands, Poland, Spain, Sweden, Turkey, United Kingdom
	No proactive grid planning	Ireland, Romania, Germany, Sweden, Netherlands, Norway, Spain, Turkey, United Kingdom
	Conservative hosting capacity calculation	Croatia, Greece, Spain
	Not enough incentives to accelerate grid planning and optimisation	Croatia, Finland, France, Greece, Italy, Romania, Sweden, United Kingdom
	No useful mapping of grid saturated areas	All surveyed countries
Procedural Inefficiencies	**Grid permitting not efficiently linked to other permitting processes**	Belgium, Croatia, Finland, Germany, Ireland, Norway, Romania
	***First come, first served* principle**	Applies in all surveyed countries apart from Greece, Spain and Norway. Ongoing discussions to change this in many countries.
	Not strict enough criteria to enter the connection queue	Italy, Turkey
	Shortage of human resources and digitalisation	Croatia, Finland, Germany, Greece, Ireland, Italy, Norway, Romania, Turkey
	Not enough incentives to accelerate the assessments	Belgium, Croatia, Greece, France, Ireland, Italy, Romania, Sweden
	Lengthy grid equipment procurement processes	Romania, Sweden

Source: WindEurope

1.4 National strategies to improve connection queue management

When assessing new grid connection requests, System Operators typically adhere to the *first come, first served* principle. But some countries have or are starting to implement strategies for dynamic and smarter management of grid connection queues.

The objective is two-fold. First to filter out or deprioritise speculative projects that have made it to the list without being sufficiently mature or viable for deployment. We call these **filtering** criteria. Second, among mature and viable projects, to prioritise grid connection assessment for those that better fulfill strategic or system integration criteria. We call these **prioritisation** criteria.

In terms of filtering, many counties such as France, Greece, and Romania have stricter entry criteria to the waiting list. They need to offer proof that the project has already achieved key milestones by securing other key authorisations across the permitting process. In other countries like Croatia this proof is only required much later when the project is about to get connected. This is not helpful when it comes to dynamically managing the list in terms of project maturity.

Some countries e.g. the Romania and the UK ask for a substantial application fee to be paid by the project developer for the preliminary grid connection assessment (between €10-100k in Romania depending on project capacity, and €60k in the UK for all projects). In other countries such as Sweden this preliminary assessment is free of charge.

Many countries require financial commitments, such as bank guarantees that the project will be developed for the System Operator to reserve grid capacity. This is the case in Greece, Italy, Romania and Spain. The idea is that the developer will lose this money (for instance in Romania 10% of the total connection fee on average, in Greece approximately €20/MW of installed capacity) if the project does not use the reserved grid capacity. In some cases, though, when a project fails to go ahead, the reserved grid capacity takes too long to be released again for new connections. This is often the case in Italy for example.

Spain and the UK also apply a “milestone achievement” principle to dynamically manage the lists. In January 2024, the UK launched new procedures to filter grid connection requests. The proposal recommends striking slow-moving or stalled projects from the transmission connection queue. Greece has introduced three milestones: a bank guarantee to reserve grid capacity, a deposit for the signature of the grid connection agreement (up to €250k), and an obligation to apply for a grid connection agreement and installation licence during the first year of applying for the bank guarantee - even though the latter lasts for three years.

In Spain if a project does not reach key maturity milestones it loses its bank guarantees, gets archived and removed from the list. It would need to start the process all over again if it is still looking for a grid connection. Norway has identified 4.2 GW of projects in the connection queue that can already be labelled as mature - reserving grid capacity for these.

In terms of prioritising, not many strategies apply as it stands. In Ireland the top 25 renewable energy projects delivering the most energy annually (with higher capacity factors) are prioritised on the list. After that, the other projects are ranked based on the earliest date when planning permission is obtained. This approach ensures that projects with early planning consent can secure a connection offer before expiration. In Romania authorities have considered prioritising projects for 2 or 3 geographical regions with low total renewable capacities.

In other countries like Greece the authorities are looking at technical criteria that could be used for the prioritisation. With a new law introduced in August 2022 the *first come, first served* approach has been dropped. But there is also a big disparity between solar and wind capacity on standby. PV projects, being quicker to license with less public opposition and smaller scale, receive priority and support from authorities that favour smaller but more numerous developers. This has led to an unbalanced mix of renewable technologies connected to the grid.

Indeed, thoughtlessly allocating grid capacity to significant PV volumes in the same areas, based on the *first come, first served* approach, has led to structural grid congestion during sunny periods. Smarter grid capacity allocation for new connections (or a prioritisation approach) would have allowed the complementary nature of different energy sources to be exploited - such as a mix of wind and solar to maximise the use of available grid capacity.

Spain is a unique case. Since 2020 authorities have decided on a system based on tendering processes per substation, for most high-voltage substations. This system awards points and prioritises projects which meet certain technical, environmental or social criteria. To our knowledge the system has been difficult to implement and has not yet been put in place. The new proposal[6] in the UK calls for a review of the *first come, first served* approach with alternative

6. National Grid ESO, GB Connections Reform, 2024

methods for allocating capacity more efficiently in line with long- and short-term net-zero goals.

A workable solution could be to identify certain categories of projects that should be prioritised among the rest and then treat the projects within these categories with the *first come, first served* approach. In our view it would be better to base this prioritisation on technical system integration criteria - since it is very hard to compare technical benefits with environmental or social ones. For instance, after achieving milestones of maturity, projects co-locating with different generation technologies and/or storage at the same grid integration point could be prioritised. The same could apply to projects designed with advanced grid support capabilities.

Finally it is worth noting that not many countries publish up-to-date maps showing grid capacity available for new connections. Many countries such as Belgium[7], Finland, France and Romania are in the process of developing or updating these tools. This will also become mandatory under the provisions of the recently revised Electricity Directive. In countries with grids that are already highly saturated, these maps can help asset developers to evaluate start areas based on grid availability as well as wind resource.

1.5 Recommendations to improve grid connection processes

Two key European regulations - namely the revised Renewable Energy Directive (RED III) and the EU Emergency Permitting Regulation - came into effect in 2022. These regulations call for expedited grid connections for new and repowered renewable installations. However, many countries have not yet implemented these new rules, even though the Emergency Regulation on permitting is currently in force and RED III must be transposed by 1 July 2024. In some countries like Croatia, Belgium, Germany, Greece, Ireland and Italy efforts to finalise this are underway.

The national implementation of these regulations could set a framework for accelerating the connection of new or repowered assets in designated renewable acceleration area. However, as it stands only a handful of countries are actively exploring strategies to ramp up the expansion and connection of renewable energy. Croatia for example has considered launching a sensitivity map as part of its NECP. It would feature designated renewable acceleration areas that will need to be capable of hosting a grid connection.

In Greece, Ireland, Italy and Sweden grid expansion in “Renewable Acceleration Areas” will also be ramped up. But for some countries like Greece, even though the TSO framework for accelerating projects and of public interest is excellent, these projects face public opposition and legal challenges especially for high voltage grids. Proper stakeholder engagement from as early as possible and a faster system for court decisions would be particularly helpful.

The principle of overriding public interest needs to apply to the permitting of grid infrastructure - regardless whether it is explicitly to connect renewables or for grid reinforcement at higher voltage levels. Delays in reinforcement at higher voltage levels are often the biggest cause of delays in connecting renewables to the grid - even when they are due to be connected at the distribution level.

Proper planning and anticipatory investments in grid expansion, reinforcement and efficiency are are all key to allocating sufficient capacity to renewables and new electrified demand. **First, the NECPs need to be updated to ensure that network infrastructure, at all voltage levels, can accommodate the overall targets for renewable capacity and electrified demand. They also need to ensure that sufficient grid capacity will be allocated – in a balanced manner - to all strategic technologies in order to reach national targets.** For the latter a good example has been applied in Greece for offshore wind. Based on a recent ministerial decision, grid capacity in designated broader grid areas has been reserved for the integration of offshore wind - instead of being allocated based on the *first come, first served* principle.

As for grid connection queues, the right entry criteria is vital. Projects should only be able to apply for a grid connection once they have achieved key maturity milestones in their permitting processes and have made adequate financial commitments such as bank guarantees. But these maturity milestones should also be smartly designed to avoid delays due to other inefficient procedures in the general permitting process.

Also, these strategies need to bear in mind that lead times can differ significantly depending on the technology - for on and offshore wind and solar PV. Environmental impact assessments are usually much longer for wind farms than for solar PV parks for example.

National authorities should carefully consider strategies to remove or deprioritise stalled projects in the connection queues. Once in the queue should not mean always in the queue. Also, they should abandon the *first come, first served* principle and use prioritisation criteria that can get us on track to meet our net-zero targets. This would mean prioritising projects which offer better system integration through e.g. hybridisation with other generation

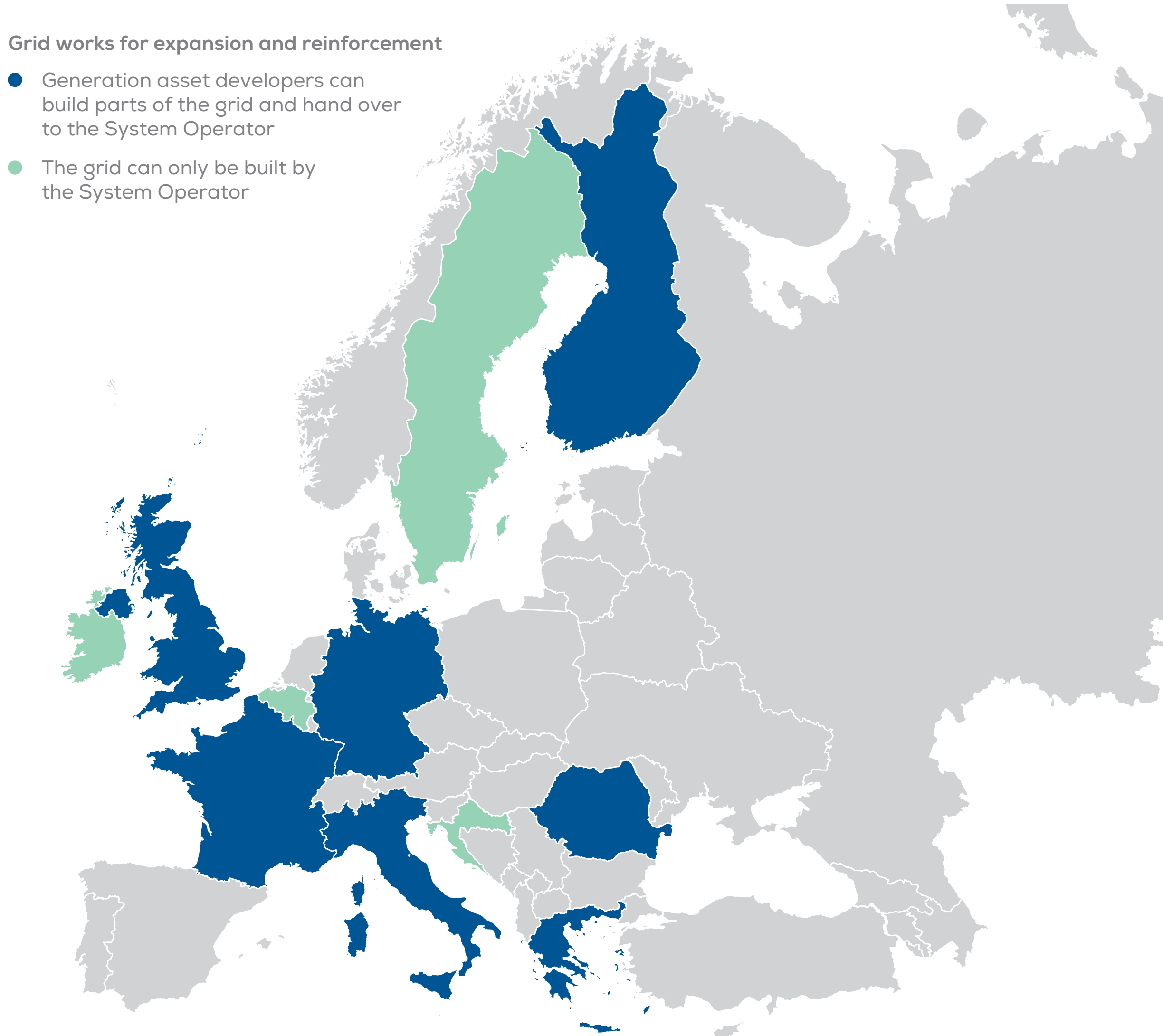
7. Good references are the grid capacity maps by the Belgian DSO Fluvius (map) and TSO Elia (map).

technologies or storage, behind-the-metre colocation with demand or advanced grid support capabilities.

Given the scarcity of technical and human resources needed to expand the grid, the regulatory framework in all countries should allow generation developers to pre-finance and develop part of the grid infrastructure. Based on a pre-defined agreement between the TSO and the generator, the relevant grid infrastructure would then be handed over to TSOs with adequate compensation.

In some countries such as France, Finland, Germany, Greece, Ireland, Italy, Romania and the UK (Figure 6) the regulatory framework already enables such possibilities. In France this is possible only at distribution level and in Italy only for substations up to 220 Kv, but not for high-voltage lines.

FIGURE 6. Possibility for generation asset developers to undertake grid expansion works



Source: WindEurope

2.

Grid charges

Grid access charges in most countries are made up of two key components - the **charges for connecting** a specific asset to the grid, and the **charges for grid expansion** and **reinforcement** to allow for this grid connection and others like it.

Grid connection charges refer to the costs involved in connecting a specific asset to a substation on the public power network. They are mostly based on the CAPEX of electrical infrastructure such as substations, transformers, cables and metering equipment needed for the connection of the new asset to the public network. The total figure for these charges comes down to several factors - including the wind farm's capacity, the location and the precise grid connection criteria as determined by the national or regional grid operator.

Grid expansion and reinforcement charges refer to the costs involved with expanding and reinforcing the public electrical network so that it can accommodate new generation and demand assets.

Both types of charges are subject to different regulatory frameworks across Europe. Understanding and managing them is critical for wind farm developers and investors since it determines a project's economic viability. There are different options when it comes to responsibilities for covering grid connection, expansion, and reinforcement costs by generation asset developers:

- **Super-shallow:** both charges are socialised via the network use tariffs and no costs are shouldered by the asset developer.
- **Shallow:** the asset developer pays the project-specific grid connection charges.
- **Deep:** the asset developer covers the grid connection charges and all grid expansion and reinforcement charges too.

In most of Europe asset developers are required to pay their grid connection charges (shallow). Depending on the country and whether the connection is onshore or offshore, the grid expansion or reinforcement charge needs to be covered either by the asset developer or by the System Operator - or by a combination of both. In some countries asset developers have to cover the grid expansion charges but can ask for contributions from other developers connecting their assets later in the same grid area.

In the two following subparagraphs we will give an overview of how requirements on grid charges apply in the different countries looked at in the survey. We will also look at how they affect the diversity of costs covered by developers.

2.1 Charges for grid connection

In most cases grid connection charges include a cost for the technical assessment by the System Operator, the CAPEX of the necessary equipment and the work to lay the electrical connection to the public network. In some countries such as Belgium and Sweden an annual fee for grid access also applies.

The total amount charged for the grid connection is usually determined by the total installed capacity of the asset (€/kVA), the distance to the closest or the System Operator's proposed substation, the voltage level the asset is connected to, and the need for additional technical equipment - for the electrical connection or security such as alarms or metering devices.

In countries like Belgium, should the DSO recommend a substation other than the nearest one, they are expected to cover the additional cost, which is capped to a fixed amount - €56k/MVA. If the necessary grid connection costs are higher than this cap, the asset developer needs to cover the rest even if the substation has been indicated by the DSO - despite not being the closest one.

These charges are usually universal regardless of the generation technology. As it stands in most countries the same system applies for onshore and offshore connections. But assessments are ongoing to work out different charges.

The annual grid access fee – where it exists – is defined annually by the System Operator and approved by the energy regulator. In most countries the grid connection charge is fully covered by the asset developer. There is a good deal of variation when it comes to covering the costs of grid expansion - as explained in the next paragraph.

2.2 Charges for grid expansion and reinforcement

The charges for grid expansion and reinforcement which the public network need to integrate a new asset's capacity can range widely across Europe.

These charges are very much defined by the geographical location of the asset, the existing grid capacity in the area, the voltage level and the equipment that needs to be installed. This charge component is often given a low estimate for connections to the high voltage network - compared to estimates for connections to medium or low voltage.

In some countries such as Germany the System Operator is responsible for covering onshore grid expansion and reinforcement charges. In others like France, onshore grid expansion charges are shared between developers connecting in the same administrative area - varying between €30-80/MVA. These fees are regularly updated, which leads to uncertainty and extra standby time for asset developers.

As things stand, in Belgium, Croatia, Denmark, Estonia, Greece and Spain the developer is expected to cover the entire cost for grid expansion and reinforcement. In Croatia these charges are set unreasonably high (around €100k/MVA) for projects in the existing grid connection queue. The TSO has recommended trying to recover the steep grid reinforcement costs from the project's connection fee - and not just accommodating these specific requests (the 400 kV line between Dalmatia and the rest of Croatia).

Greece recently brought in a new law that calls on asset developers and the TSO to share half of the charges for grid expansion and reinforcement. The first asset developer in a specific reinforced area will be charged the entire developer share and will be reimbursed by other developers connecting later in the same area.

When it comes to offshore wind, in many countries like France, Germany, and Greece the TSO will cover all grid expansion costs - including the offshore substations and connections to the onshore grid. The asset developer will cover grid connection charges from the wind farms to the offshore grid substation.

Table 2 looks at how grid charges are allocated across several countries.

TABLE 2. Allocation of grid connection charges

Grid charges	BE	DE	DK	EE	EI	ES	FR	GR	HR	IT	NO	RO	SE	TR
Grid connection charges covered by generation asset developer (from generation unit to public substation)														
Application fee for TSO technical assessment														
CAPEX and works for connection														
Annual fee for grid usage														
Additional technical equipment	At TSO level													
Variation across voltage levels														
Grid expansion and reinforcement charges														
Covered/shared only by developer(s)														
Shared with System Operator	At TSO level		Meshed grids											
Covered only by System Operator														
Locational variation														
Offshore covered by System Operator														

3.

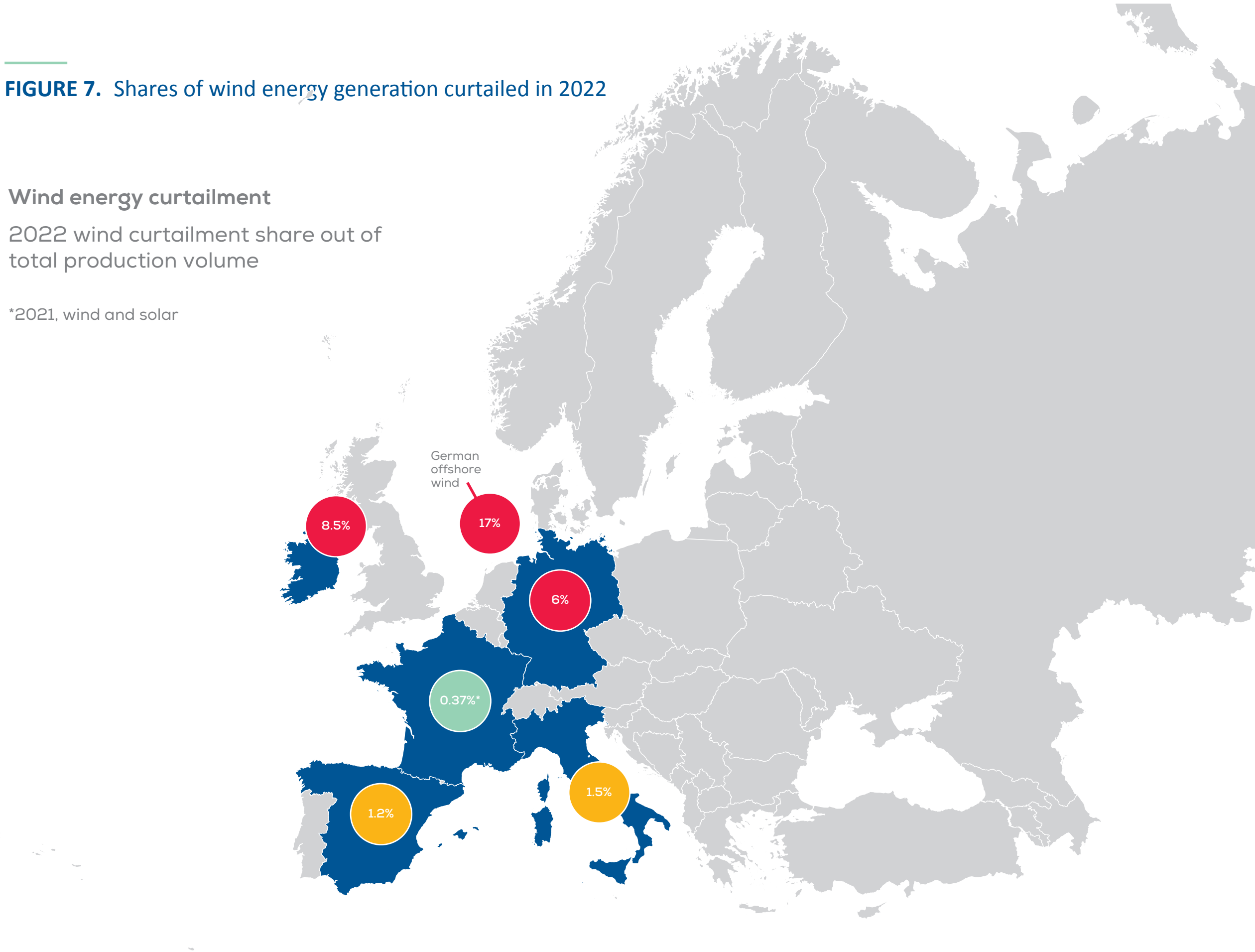
Curtailment of renewable energy

3.1 Curtailment and compensation

In many European countries grid congestion is growing because of mismatches between power supply and demand at different timeframes, and insufficient roll out of storage and demand response solutions. Renewable generation is severely hampered by this - and high congestion management costs are also passed onto the network tariffs for end-users. This is already a source of concern in certain countries like Germany or Ireland and continues to grow in others such as Spain, Italy, France, Greece, and Romania.

The vast majority of System Operators in Europe do not publicly share data on curtailed volumes and congestion management costs. As it stands it is extremely challenging to have a clear overview of these costs at European level and to compare with investments in grid expansion and flexibility that could be deployed instead. Figure 7 shows the proportion of total wind energy generation curtailed in 2022 - using publicly available data from certain European countries.

FIGURE 7. Shares of wind energy generation curtailed in 2022



Source: WindEurope

Existing EU regulation calls for asset developers to be compensated for their curtailed volumes using a market-based approach. But very few countries have actually applied this rule. In those countries where renewable curtailment is compensated, System Operators apply administrative compensation to asset owners for their curtailed production.

Figure 8 shows those countries which compensate asset owners for curtailment imposed by the System Operator, and other countries with no compensation scheme. In most cases this compensation is calculated based on respective unit prices in the day-ahead electricity market as is the case in Belgium, France and Germany.

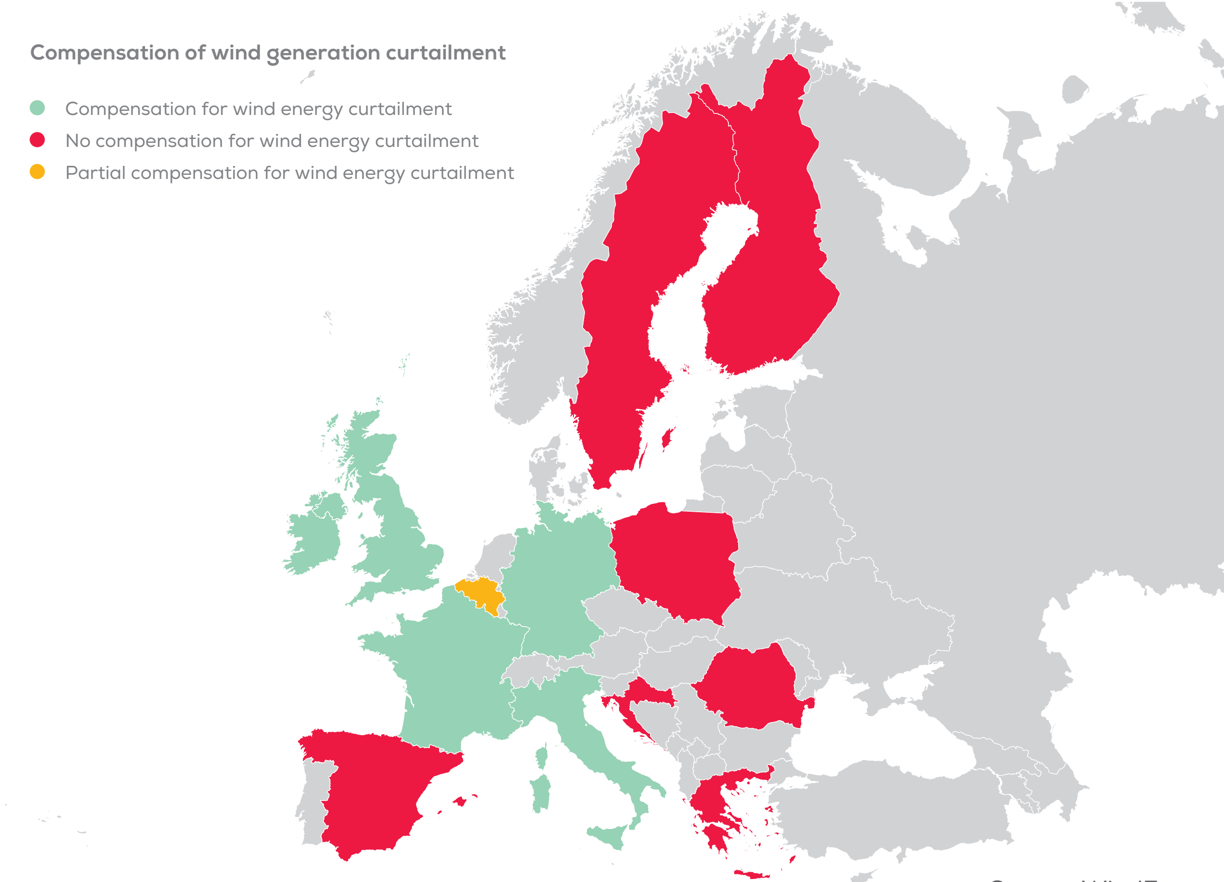
By contrast Croatia, Greece, Finland, Poland, Romania, Spain and Sweden do not currently offer compensation for renewable curtailment. Some of this is due to technical reasons such as insufficient grid capacity. In Greece and Romania asset developers are obliged to accept grid connection agreements which impose operational curtailment in order to access the grid. All this means that asset owners for new projects have great difficulty reclaiming their curtailed production and seeking compensation - despite the promises of European legislation.

In Italy wind farms are compensated for curtailment but not solar PV. In France developers are compensated for their curtailed volumes but the whole compensation process is very drawn-out. This means there is very little clarity for asset owners on when they can expect to recoup their missed revenue. And so curtailment continues to be a high risk factor for investment viability. Meanwhile in the UK, curtailment is compensated through the balancing market - effectively a fully market based approach.

Some countries allow negative pricing in their day ahead electricity markets. This often leads to voluntary – market-based – curtailment by asset owners except in cases where asset owners are losing their long-term stabilisation contract payments once they stop injecting into the grid.

In Belgium, Germany and Italy assets are compensated for the first hours of negative prices e.g. for the first 6 hours in a row. In the UK and Germany this compensation is up to the strike price in the contracts e.g. 2-sided CfDs that the assets are in. In the UK compensation during negative pricing hours will gradually be phased out in the next capacity auction rounds. In Ireland asset owners are not compensated during hours with negative prices.

FIGURE 8. Compensation for wind generation curtailment across Europe



Source: WindEurope

When it comes to priority of dispatch, the practice varies across Europe. In France and Germany this is cost-based so the cheapest technology – in terms of curtailment compensation – gets curtailed first. In Ireland wind has priority of dispatch over other technologies, while in Italy it can expect to be curtailed after hydroelectric power when needed, but before solar PV assets. In other countries like Croatia or Romania practically all renewable energy assets have the same status of priority - which means the judgement rests with the professional opinion of the System Operator.

3.2 Flexible grid connection agreements

To streamline curtailment and accelerate grid access in congested areas, some countries have already introduced a new option - flexible (non-firm) grid connection agreements. In Belgium these agreements can already be arranged at the transmission level and an adaptation of the framework is under stakeholder consultation. One possible configuration is that the agreement will apply with a share of the asset's capacity being liable to be cut off without compensation, whenever this is deemed necessary by the System Operator. But this would also come with a cap on the total energy volume that can be curtailed annually without compensation.

In Ireland the framework for firm connection agreements is completely different than in other countries, even though it is currently being updated. The TSO recommends offering time-bound firm connection agreements, to be reviewed on a yearly basis, with the firm threshold also updated annually. This review will also indicate new areas where time-bound firm connection agreements will be possible, as well as the possibility of partial firm access which can be granted in blocks. Firm connection agreements will only be possible for assets with a capacity greater than 1 MW.

In Germany and Belgium, flexible connection agreements are possible, but only apply in specific individual cases. Norway also allows flexible connection agreements for generation and demand based on bilateral agreements. In Finland and Spain there are discussions on allowing temporary flexible connection agreements. And in the UK both temporary and permanent flexible connection agreements are possible.

4.

Hybridisation

An effective way to maximise the use of existing and future grid connections and to mitigate curtailment is through co-locating different renewable generation technologies, with or without storage, that share the same grid access point. **Even though such assets have been shown to bring major system integration benefits and asset developers are interested in developing them, very few countries - notably Spain and Portugal - have recognised them in their regulatory framework**.

In most national frameworks, co-located power plants are seen in the same light as any other renewable generation asset. But they have different technical characteristics which should be acknowledged to streamline and simplify their grid permitting. As it stands most national authorities and System Operators usually end up treating these assets in terms of grid connection on a case by case basis, rather than a standardised one. All this makes co-location permitting cumbersome and risky.

Hybrid assets of this kind are only viable when regulation allows for the maximum exportable or withdrawable (when storage is included) capacity in their grid connection agreement to be lower than their total installed capacity. This is the only way to benefit from complementary wind and solar generation.

Some national regulatory frameworks allow this, as is the case with Croatia, Denmark, Estonia, Portugal, Romania, Spain and the UK. In France this is only possible for assets under than 17 MW which is very restrictive. In Ireland and Finland there are plans to create a similar framework and in Germany it is possible only with some System Operators. Meanwhile in Italy this option isn't available for the moment.

Since hybridisation has not been established in most national regulatory frameworks, these assets are also treated like any other renewable generation asset in national energy auctions and when long-term revenue stabilisation contracts are allocated. When these auctions are only based on price criteria, co-located renewables or co-location with storage is practically deprioritised since these assets often have a higher initial CAPEX than single technology assets. The co-located generation technologies should have different, technology-specific, long-term revenue stabilisation contracts. This is the case in Croatia - but their metering needs to be adapted to this.

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