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Planning for renewables in an uncertain world: key takeaways from analysing the German onshore approach

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ABSTRACT

The study addresses planning related regulations for the expansion of onshore wind turbines (OWT) and ground-mounted photovoltaic (GM-PV) based on the example of Germany – a pioneering country for the expansion of renewable energies, in which some innovative planning approaches have been implemented in recent years. The strengths and weaknesses of the complex multi-tier framework are identified, and content-driven options for further improvement are outlined – flanked by a theory-orientated discussion. Emphasis is placed on a sensible spatial distribution, taking energy system-related requirements and increasing military threats into account. Many theoretical findings are general in nature, and the corresponding recommendations may be transferable to other countries in Europe (and beyond). Some relate directly to EU Directives.

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1. Introduction

In the European Union (EU) amendments to the Renewable Energy Directive (EU) 2018/2001[1] (RED) by Directive (EU) 2023/2413[2] (RED III[3]) require significant adjustments to national planning frameworks for the expansion of renewable power. In addition, the increasing urgency of climate protection and – exacerbated by Russia's war of aggression against Ukraine and fears of further attacks on other parts of Europe – the need for a secure power supply mean that corresponding regulations in European countries must be optimized.

Germany provides a useful case for examining planning approaches to renewable electricity. Its shift toward a largely renewable power supply has generated innovative planning solutions. This article assesses these approaches and makes the findings available for international debate. Thereby, drawing on Suitner/Levin-Keitel, it contributes to transition debates through a planning lens attentive to space, governance instruments, and long-term futures (Suitner and Levin-Keitel 2025, 477), considering also the technical and systematic needs of transforming the energy system.

Moreover, this article advances recent debates on security-related challenges for planning (ARL 2025) by offering a targeted analysis of the spatial impacts of geopolitical risks

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and related interactions between planning levels and sectoral law in the energy transition. It thereby extends the reform debate (see, e.g. Günnewig et al. 2022; Wegner 2022) and outlines ideas for refining planning-related regulations.

Wind and solar energy are expected to be the cornerstones of future electricity generation in Germany, but for subnational spatial planning practice, two deployment types are particularly relevant: onshore wind turbines (OWT) and ground-mounted photovoltaic (GM-PV) installations. After a focused introduction to the regulatory context (Section 2), the paper outlines the current multi-level planning and regulatory framework governing OWT and GM-PV in Germany, including recent changes (Section 3). It then provides a comprehensive assessment (Section 4) and derives recommendations. Finally, the findings are discussed in relation to relevant theoretical literature, and conclusions are drawn (Section 5).

Against this backdrop, the central research question asks what the strengths and weaknesses of the current German approach are and which regulatory measures – including sector-specific measures relevant to planning – could further improve it.

Thus, the aim is not only to assess current planning and regulatory practice, but above all to generate new 'envisioning' contributions that inform future-oriented improvements (Kindermann et al. 2024, 30) – already highlighting the potential transferability to other countries, particularly European ones, where relevant. Accordingly, this article is grounded in conceptual thinking as defined by MacInnis (2011, 140) and aligns with Yadav's (2010) emphasis on the importance of conceptual contributions for the long-term robustness of academic disciplines.

The methodology is based on a critical appraisal of the current multi-tier regulatory system relevant to planning for OWT and GM-PV, utilizing a document-based investigation to formulate evidence-driven recommendations. Legal materials were retrieved via iterative searches in juris and beck-online, and the international literature was surveyed using Scopus and Web of Science, supplemented by targeted web searches via Google to identify relevant grey literature. Sources were selected for inclusion based on relevance to the identified regulatory interconnections, authority, and doctrinal significance. Furthermore, the study is informed by the researcher's professional experience in spatial planning.

2. Regulatory context of the German planning framework for wind and solar power

2.1. New challenges posed by the RED

Article 3(1) RED stipulates since RED III that the share of renewables in gross final energy consumption is at least 42.5% by 2030 (non-binding target: 45%) – a significant increase from 24.5% in 2023.[4] Article 4, point (a) number 2 of Regulation (EU) 2018/1999 provides Member States (MS) with corresponding indicative timelines and Article 3(4a) RED requires MS to ensure corresponding national frameworks – with solar and wind energy most likely playing the leading roles (Pickering, Lombardi, and Pfenninger 2022, 1264).

MS therefore must review and, if necessary, adapt the national regulatory planning framework for renewable energy. This makes sense anyway regarding OWT and GM-

PV, because – according to an exemplary analysis of six countries – the hurdles for market-integration of these technologies are high and diverse in Europe – including 'insufficient spatial planning' (Bartoszewicz-Burczy 2022, 70).

The EU supports the intended review and change-processes with new rules on recording, planning and authorization – introduced via RED III. The new key planning-related elements are renewables acceleration areas (RAAs) (Article 15c RED). These have to be defined in plans, for which an assessment must be carried out in accordance with the Strategic Environmental Assessment (SEA) Directive (SEAD) 2001/42/EC[5] (Article 15c(2) RED). Article 15c(1) RED stipulates that RAAs should be relatively free of environmental conflicts.

In order to speed up and simplify processes, the obligations to carry out an environmental impact assessment (EIA) under Article 2(1) of the EIA Directive 2011/92/EU[6] and an impact assessment under Article 6(3) of the Habitats Directive 92/43/EEC[7] usually do not apply to project approval in RAAs, subject to detailed provisions of Article 16a RED. To limit environmental impacts, rules for mitigation measures must be laid down at plan level and applied, where necessary (Article 15c(1), point (b) RED). Additionally, approval timelines have been capped (Article 16a(1) RED).

2.2. The envisaged role of wind and solar power production in Germany

Trends like electromobility, heat pumps, artificial intelligence or electrification of industrial processes enhance the importance of electrical energy. Regarding sources, Section 1 of the Renewable Energy Sources Act 2023 (EEG)[8] stipulates that Germany's electricity supply should be based exclusively on renewable energies in the long term and that the share of electricity consumption from renewable sources should reach at least 80% (gross) by 2030 – the latter being within reach (EWI, BET 2025, 70).

Mainly wind turbines and PV are to be expanded (Section 4 EEG) – in line with long-term scenarios (Naegler et al. 2021, 10). However, since this article focuses on supra-local spatial planning on land, only GM-PV and OWT will be examined in more detail below – technologies that are currently mostly financed by using EEG subsidy models with tenders playing the central role (Deutscher Bundestag 2024a, 9–14; 22).

According to Section 4 No. 1 EEG, OWT capacity is to be increased – in defined steps – from 63.5 installed megawatts (MW) at the end of 2024 (Quentin 2025, 12) to 160 gigawatts (GW) by 2040 (Section 4 No. 1 EEG).

The total installed solar capacity of circa 99 GW at the end of 2024 (Agora Energiewende 2025, 50) shall increase stepwise to 400 GW by 2040 (Section 4 No. 3 EEG). Half of the extension is to be realized via GM-PV (Deutscher Bundestag 2022, 3, 183).

However, a high population density, natural restrictions and other factors limit especially the potential for wind power in Germany (Guidehouse Germany 2022, 24–31). Furthermore average wind speeds significantly decline from north to south[9] and solar radiation in Germany is much lower than, for example, in Mediterranean countries.[10] Thus, the usable spatial potentials for PV and especially OWT in Germany are more restricted than in France, Spain, Italy or the UK (Dupré la Tour 2023, 8–9).

3. The planning-related German regulatory framework for OWT and GM-PV

3.1. OWT

3.1.1. A short look back

Before recent fundamental legal changes (Section 3.1.2), it was difficult to designate sufficient areas for OWT in a legally secure manner. Many problems were related to high requirements for concentration zones (Wegner 2022, 4–7). By these zones, planning authorities in the multi-level German planning system (Danielzyk and Münter 2018; Münter and Reimer 2023, 665–666) – illustrated in Table 1 – were able to restrict the general authorizations facilitating privilege for wind energy in the undesignated outlying area (Section 35(1) No. 5 and Section 35(3) sentence 3 of the Federal Building Code (BauGB)[11]). Among other negative factors were blanket regulations of some of the 16 German states regarding minimum distances from residential uses (Römeling 2023, 24–25).

OWT were mainly installed in northern Germany (Quentin 2025, 13). This is remarkable in that there is also considerable – albeit not unlimited (Dupré la Tour 2023, 8–9) – potential in the south (Guidehouse Germany 2022, 26; Pape et al. 2022, 51–84) – and investors have long been granted project-dependent compensation for differences in wind power potential between regions – currently via Section 36 h EEG.

More importantly, measured against targets of the Wind Area Requirements Act (WindBG)[12] the usable area for OWT secured in plans had to be quadrupled (UBA 2023, 101).

3.1.2. Recent alignments

Against this backdrop, the WindBG and associated regulations, including Section 245e BauGB and a new version of Section 249 BauGB, were introduced in 2022 by the Act to Increase and Accelerate the Expansion of Onshore Wind Energy Plants.[13] This was preceded by a scientific debate with numerous conceptual contributions – summarized by Wegner (2022) – on better steering options and possible roles of spatial planning, land-use planning and specialized law.

The WindBG now stipulates via Section 3(1) sentence 1 in conjunction with state-specific minimum area targets (MATs) in the annex that at least 2% of the federal onshore area must be secured for OWT by 31 December 2032 at the latest – with lower interim targets specified for 31 December 2027. The different MATs are roughly

Table 1. German Statutory Planning System – Provisions Relevant to OWT and GM-PV (simplified). Source: Created by the author.

Level	Main Legislation and Plans Relevant to Onshore Wind Turbines (OWT) and Ground-Mounted Photovoltaic (GM-PV)
Federal Level	Federal Spatial Planning Act (Raumordnungsgesetz – ROG) Federal Building Code (Baugesetzbuch – BauGB)
State Level (Länder)	State Spatial Development Acts (Landesplanungsgesetze) State Development Plans (e.g. Landesentwicklungspläne) in Most States
Regional Level (most States)	Regional Plans (e.g. Regionalpläne)
Local/Municipal Level	Preparatory Land-Use Plans (Flächennutzungspläne) Binding Land-Use Plans (Bebauungspläne)
Selected Sector-specific Federal Legislation	*Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG)* *Wind Area Requirements Act (Windenergieflächenbedarfsgesetz – WindBG)*

based on a nationwide potential-study (Guidehouse Germany 2022). States can adopt more ambitious targets (Section 3(4) WindBG).

The states can fulfil MATs in their own plans or delegate them to regions or municipalities (Section 3(2) WindBG). All 12 German states that have regional planning levels have entrusted them with the task (Rheinschmitt and Köck 2023, 1393; Gailing et al. 2025, 441). Corresponding designated areas must be observed by sectoral or local planning (Section 4 of the Federal Spatial Planning Act (ROG)[14]).

The option of designating concentration zones ended on 01 February 2024 (Section 245e(1) sentence 1 BauGB). As a replacement, OWT outside designated wind energy areas are usually no longer privileged under Section 35(1) 1 BauGB (Section 249(1) BauGB) and are subject to further restrictions in Section 249(2) Sentence 1 BauGB if MATs are met – drastically reducing prospects for approval. This largely corresponds to the concept of conditional partial spatial deprivileging, only developed in 2021 (von Seht 2021, 614–616).

However, if and unless MATs are fulfilled after the cut-off dates, the (unrestricted) general privilege of wind energy use does apply in the whole undesignated outlying area of the spatial unit responsible and most planning specifications no longer preclude wind energy use (Section 249(7) BauGB).

Finally, central rules for RAAs (Section 2.1) were introduced via Articles 28 ROG and 249 BauGB.

3.2. GM-PV

3.2.1. (Limited) spatial steering via the EEG

The EEG specifies spatial settings for participation in tenders – also taking account of technical variants of GM-PV.[15] Thus, it directs GM-PV systems into certain areas (Sections 37 and 37c EEG).

The EEG does not contain minimum quotas or limits for GM-PV in sub-areas of Germany and no compensation rules for differences in radiation. This is likely to have contributed – with other spatially varying factors, such as planning restrictions, soil quality and lease prices – to substantial, federally uncoordinated regional differences in installations. For example, in 2022, comparatively high proportions of GM-PV were installed in parts of Bavaria and Saxony (Dünzen, Krieger, and Ritter 2024, 18), both southeastern German states with high solar radiation.[16] Scenarios indicate, that under current regulations the strong concentration in certain parts of Germany will continue (FfE 2025, 31–33).

Declining GM-PV costs increasingly enable projects financed without a tender by means of power purchase agreements (Deutscher Bundestag 2024a, 28–29), diminishing the EEG's spatial steering effect (Schmidt, Roth, and Schill 2024, 512; ARL 2022, 4).

3.2.2. Planning law changes in recent years and current situation

GM-PV is gaining spatial relevance due to the EEG expansion targets, investment interests and corresponding competition for land use. At the same time, however, regional planning in Germany has rarely included an overall spatial search for and safeguarding of locations (ARL 2022, 8). Section 7(3) sentence 6 (ROG) even excludes solar energy from spatial concentration zoning – similar to Section 35(3) sentence 3 BauGB.

Furthermore, the binding effect of supra-local spatial planning objectives pursuant to Section 3(1) No. 2 ROG is essentially limited to spatially significant plans and measures (von Seht 2023, 193–195).

In 2023, a privilege for GM-PV was introduced (Section 35(1) No. 8 BauGB) – though limited (areas along federal motorways and major railways). Corresponding projects at non-critical locations can be realized without statutory planning.

The legislator has not yet exercised the option to authorize RAAs for GM-PV.

4. Assessment and recommendations

4.1. General conditions and considerations

As outlined in Section 2.2, OWT and GM-PV systems are key to the future German power production. Corresponding preconditions and considerations relevant to spatial planning are briefly set out below, followed by an assessment of the regulatory planning-related framework conditions and recommendations. Where appropriate, the extent to which initial conditions are Europe-wide is also made clear to provide an indication of transferability.

The logical starting point is the pressing need for climate protection. It is likely that warming will permanently[17] exceed the threshold of 1.5 degrees (IPCC 2023, 57–59) and Europe is warming well above average.[18] In addition, increased global warming makes abrupt negative and possibly irreversible climatic changes more likely (IPCC 2023, 77–78).

Regarding German electricity generation, there are many arguments to prioritize domestic OWT and GM-PV to combat these trends. For example, both renewables don't produce local air pollution or nuclear risks. Furthermore, in Germany they amortize quickly in terms of energy (Hengstler et al. 2021, 33, 307) and have low (though geographically varying) electricity generation costs (Kost et al. 2024, 17–20). The latter is due to sunk levelized costs in recent years, which is an international trend, as Dupré la Tour (2023, 1) stresses.

However, in the view of geopolitical tensions and growing concerns about attacks on further European countries, special energy security[19] related benefits and conditions deserve attention:

Once installed, domestic renewables involve no major import risks (Colgan, Gard-Murray, and Hinthorn 2023, 8). In contrast, such risks are linked to imports of fossil fuels and uranium. During geostrategic conflicts, exporters could stop sales, or third countries could hinder deliveries by military or diplomatic means – incidentally driving global market prices and thus negatively affecting also countries that still get deliveries. Also importing green hydrogen can entail risks (Egli et al. 2025).

Furthermore, OWT and especially area-intensive GM-PV systems are typically distributed decentrally, making it less easy to prevent electricity generation by military or terrorist attacks.[20] The importance can be learned from Russia's current war of aggression, because in Ukraine, the bitter conclusion had already been reached in 2024 that 'virtually all large, centralized power plants have been attacked since February 2022, reducing overall generation capacity to roughly a third and substantially weakening the grid via attacks on transmission lines and substations' (Doronina et al. 2024, 2719).[21]

In this respect, if European countries choose decentralized renewables and storage facilities (combined with demand-side management) instead of big conventional power plants this increases resilience.[22] The latter here refers primarily to the energy system. However, given the importance of energy, the resilience of national energy systems is also of major relevance to the broader resilience of the economy, the military complex and society – similar to what is stressed by Semeneko et al. (2025) for Ukraine. This fits with Semeneko et al. (2025, 127), Jesson (2024, 16) and Doronina et al. (2024, 2719) who similarly argue for rebuilding the Ukrainian energy system based on decentralized renewables.

Challenging and spatially relevant are the power production patterns of OWT and GM-PV:

The yield of both technologies fluctuates, though in Germany and Europe as a whole wind energy and photovoltaic energy are complementary on a seasonal basis (Kaspar et al. 2019, 124) – as illustrated for Germany in Figure 1.

This negative correlation means that significant interregional electricity exchange will be necessary if wind and solar energy expansion is geographically concentrated in different parts of a European country, especially if also poorly matched to demand centres. That applies at least when regional demand management, other renewables, power plants, or storage facilities cannot sufficiently compensate.

Power grids – also cross-border – can enable the exchange, but building new or expanded transmission lines is expensive and sometimes fraught with local resistance and conflicts. In addition, they – and associated elements like electrolyzers and converters – are also potential targets of military or terrorist attacks (see above) and could be affected by natural disasters. The same applies to hydrogen-pipelines. Such risks also drive the new offshore oriented EU Action Plan on Cable Security.[23]

The less a European region is dependent on energy transport, the lower these risks and disadvantages are. Thus, promoting complementary wind and solar use nationwide near demand locations would have advantages in this respect – but some disadvantages

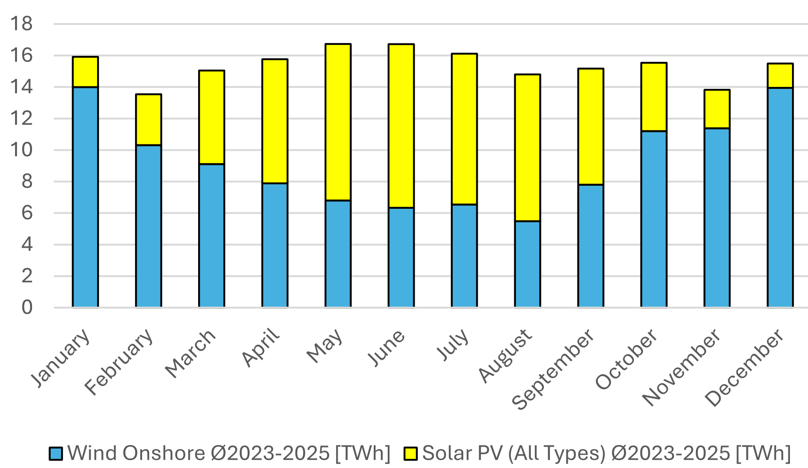

Figure 1. Average Monthly Net Electricity Production in Germany 2023-2025. Source: Created by the author using data from https://www.energy-charts.info.

regarding generation prices, if, for example, parts of countries with comparatively low radiation or wind speeds are used for OWT and GM-PV.[24]

Another point to be stressed is that complementary use does not mean equal importance:

Production times of GM-PV systems in Europe are very much concentrated around midday and during the summer of the western hemisphere when in Germany there is sometimes already too much power. Consequently Enervis (2025, 17) assumes significantly lower forward market prices in Germany per MWh for 2026–2028 for solar power than those of onshore wind power. Furthermore, wind turbines in Germany have substantially higher annual full-load hours than PV systems (Kost et al. 2024, 14; EWI, BET 2025, 64).

This performance of wind turbines is positive regarding storage requirements and the balancing utilization of gas or hydrogen using power plants. However, as already addressed (Section 2.2), the potential of OWT in Germany is rather limited compared to GM-PV and to OWT potential in some other European countries.

There are therefore good reasons to support the current, largely restriction-oriented nationwide expansion of OWT in Germany (Section 3.1.2), including the elimination of grid bottlenecks relevant to OWT, but to supplement it with a more demand-oriented (and thereby possibly grid-oriented) spatial positioning of GM-PV or PV in general.

But not only new OWT, GM-PV and power grids must fit demand. The same applies to hydrogen-pipelines, large storage facilities or power plants that compensate for temporary yield deficits – and, if possible, also cross-border.

Given the mentioned security risks, the corresponding complex energy system should ideally be dimensioned and designed so that high levels of partial regional autonomy based on renewables are possible for some time – including the options of decoupling from surrounding grids and of autonomous cold starts. Local storage systems, intelligent demand-side management and cross-sectoral energy networking could also contribute to this. Furthermore, the setup should include substantial redundancies and provisions for rapid repairs.

More emphasis on at least approaching temporary energy autonomy for larger regions could even partially mitigate problems of congested power lines and redispatch costs (Dobos, Bichler, and Knörr 2025, 1–2). Thus, it could enable more electricity in the future, even if grid expansion slows or is reduced. The appropriate size of the regions concerned and the desired degree of autonomy would need to be the subject of further analysis and political prioritization.

Nevertheless, due to structural discrepancies between areas with great potential and areas with high demand, not all regions in Europe will be able to achieve a high degree of autonomy, and yields will vary in any case. Thus, further cross-municipal and large-scale networks, storage facilities and the like are indispensable for renewable-based energy systems. In order to plan these effectively, it is important to know early on where renewables will be expanded to what extent – and ideally when – instead of having to deal with substantial uncertainties (Hermes 2014, 261; von Seht 2024, 61–62), that are partly due to numerous possible mixes and locations of renewables (Pickering, Lombardi, and Pfenninger 2022).

As will be shown, the German approach has strengths in some of the points raised, but there is still much room for improvement.

4.2. Spatial analyses

It has become clear from the above that informed and strategic spatial distribution and dimensioning of the utilization of individual renewables are advisable. First, this requires knowledge of the spatial opportunities.

Therefore, it was sensible that a Germany-wide ambitious spatial analysis of wind energy potentials was carried out by Guidehouse Germany (2022) before subsequent MATs for wind energy areas were fixed.

For this study, various scenarios were elaborated (Guidehouse Germany 2022, 16). Although the calculated potential and shares of the German states vary considerably between the scenarios, it became clear that the spatial potential for the targeted provision of 2% of the federal area is rather limited (Guidehouse Germany 2022, 24, 26).

This use of scenarios is also positive and can be a model for other countries, because the determined wind energy potential always depends on assumptions and weighting of restrictions.[25] Yet, findings of Lehmann et al. (2021) highlight that it is unlikely to find a generally accepted set of criteria. Thus, it is the logical task of elected politicians to make final decisions when it comes to setting targets, but they must be aware of the scope for action. Scenarios can serve this purpose.

Of course, national spatial potential analyses are subject to inaccuracies. However, since the German federal approach only resulted in abstract MATs for the subsequent level of German states mostly well below the possible max, such inaccuracies are acceptable. Sufficiently detailed spatial analysis on countries should even be possible as a basis for quantitative regional MATs.

The subsequent planning of formally designated individual wind energy areas can be more differentiated here and should – as in the German approach (Section 3.1.2) – not be bound to the spatial cubature of areas found in corresponding spatial potential analyses.

Room for improvement exists in German debates and spatial analysis regarding GM-PV: The latter tend to focus on the availability of conversion areas, surfaces with poor soils, areas near traffic lines or the extent of the sites according to the EEG tender framework (e.g. Günnewig et al. 2022). Even with this narrow scope, corresponding findings clearly indicate that there is much more space available for GM-PV than needed for EEG-targets (Dünzen, Krieger, and Ritter 2024, 25; Schmidt, Roth, and Schill 2024, 512) – in line with Dupré la Tour (2023, 8–9) who also found with regard to Europe as a whole, that, despite significant spatial differences, the potential for PV is much less limited than that for wind energy (Dupré la Tour 2023, 16).

As noted in Section 4.1, other factors should therefore also be emphasized. Useful would be spatial scenarios that locate GM-PV aimed at achieving a renewable-based energy system with high regional autonomy.

4.3. MATs, conditional partial deprivileging and sanctions

Arguably the most effective new elements of the German planning-related legal framework on renewables are MATs for OWT, related sanctions and conditional partial deprivileging, as described in Section 3.1.2.

With both positive and negative incentives in place, the free-rider problem (Reutter et al. 2022, 704–705) – regions and municipalities that have so far failed to fairly contribute – should no longer be an obstacle. In line with this, as Gailing et al. (2025, 434–437) have shown, the German states and regions have, at least for the most part, approached the implementation of the corresponding requirements with commitment.

In addition, MATs make it possible to estimate better than before (Hermes 2014, 261) where power grids and storage facilities are to be built and to what extent (von Seht 2023, 196–197). Furthermore, the knowledge that MATs must be observed nationwide can promote acceptance.

Such advantages of MATs and associated positive and negative incentives are likely to remain in place even if the ideas are transferred to other countries as they are based on universally applicable mechanisms.

Nevertheless, the handling of spatial distribution in Germany is partially questionable: The idea of comprehensive wind energy related MATs for German states and state MATs for regions – based on potential analyses – has already been proposed in 2010 (von Seht 2010, 277–279) and similar ideas have been made afterwards (Wegner 2022, 11–15). Given the urgency of the energy transition, one proposal was for the federal government to engage regions directly through (mainly) potential-study-based MATs in the ROG – avoiding further target-setting processes at the state level (von Seht 2021, 611–615) and legally possible (Wegner 2022, 19). However, in the regulations of 2022 only the German states were addressed via specialized law, presumably primarily to avoid deviations (possible under the ROG). Some states then allocated their targets by applying the same area-based percentage across all regions (Rheinschmitt and Köck 2023, 1391–1393). This is problematic given uneven and limited regional OWT potentials. For this reason alone, countries in a similar situation wishing to adopt the German approach should at least consider setting directly differentiated targets for regions.

A positive aspect is that Germany opted for time-bound MATs instead of performance targets (capacity or yield). Planners cannot reliably anticipate deployment schedules, technical types and yields. Performance targets would force planners and politics to make vulnerable forecasts. Given these general causal mechanisms, this is not unique to Germany. It is better if the national level prepares differentiated forecasts of land requirements, introduces corresponding MATs, and then – similar to Section 7 WindBG – monitors, and adjusts MATs if necessary.

Furthermore, Germany has not made the mistake of using targets irrespective of the energy form (with conversion keys for different renewable-technologies). For the reasons given in Section 4.1, it matters – also in other countries – what type of renewables are expanded where, to what extent and whether they can be planned for. In addition, finishing planning processes would become more difficult if, for example, planning authorities could always get under pressure to replan and provide for GM-PV instead of possibly locally unwanted OWT. In total, that is more important than political leeway.

Regarding GM-PV, as outlined (Section 4.1), it makes sense to strategically plan or at least influence the contributions of specific national sub-areas – with an emphasis on high levels of regional self-sufficiency. Thus, the federal government should introduce MATs also for GM-PV (for German states or regions) – an option likewise for other countries. This should be flanked by incentive-setting planning relief (Section 4.5), if not additional compensating sanctions such as a conditional extension of the privileges under Section 35(1) No. 8 BauGB.

However, given the separate types of GM-PV a differentiated approach is required by countries. Furthermore, specific to Germany, it must be considered, that – unlike wind energy – there is substantial spatial potential for GM-PV (Section 4.2), that many German states and local authorities in radiation-rich areas support its expansion and that in some cases (Section 3.2.2) local planning currently is not even necessary for an authorization. Therefore, without adjusting the economic framework (Section 4.6) or additional federal restrictions (von Seht 2023, 191–194), it may not be possible to fully achieve any desired spatial shift of expansion.

4.4. Implementing planning levels and instruments

A fundamental question is whether MATs should ultimately target regional or land use planning for zoning. The German approach for OWT to finally address mainly regional planning (Section 3.1.2) makes sense here and should also be applied to GM-PV. Due to the larger planning areas, there is more room for manoeuvre, e.g. to react to detailed information that emerges during planning processes. In this way, competing spatial requirements can be balanced on a large scale. At least given a scope of expansion as in Germany (Section 2.2), this is important.

There are also several European countries where regional planning is in place (Smas 2022). So, this level of governance could be taken in charge outside Germany as well.

However, both regional and local land-use planning has strengths – especially compared to certain administrative planning approval procedures proposed as an alternative regulatory approach for OWT (Kümper 2021, 1061–1067). They can ensure democratically legitimized decisions are brought about in transparent procedures (including opportunities for participation and legal action – due to the SEAD similar in other MS) and with a spatially comprehensive and sufficiently detailed weighing of interests.

4.5. Planning procedures, SEA and related authorisation issues

The new German regulatory system for OWT is associated with an innovative approach to speed up the implementation of federal planning objectives. It allows to reduce the involved planning levels.

This is because (a) of the privilege under Section 35(1) BauGB in wind energy areas and (b) the immediate elimination of the exclusion effect of any concentration zone concepts when MATs are met (or by 31 December 2027 at the latest) according to Section 245e(1) BauGB. Adapting local plans to the new regional zones thus is no precondition for project approval.[26]

A similar idea ought to be implemented for GM-PV in Germany. GM-PV systems within areas secured for this purpose in regional or general local land-use plans should also be privileged (von Seht 2023, 198–199). Further planning (e.g. detailed development plans) then is no longer required. A draft bill (Deutscher Bundestag 2024b, 18) was already moving in this direction but did not pass before the early federal elections 2025. If privileges in solar energy areas were combined with MATs subject to sanctions (Section 4.3) and spatially steering economic framework conditions (Section 4.6) the positive effects on a sensible expansion of GM-PV would be even stronger.

Coordination between different levels is not seen as a specific German obstacle to renewable energy projects (CERRE 2024, 27). Since OWT and GM-PV as project types do not necessarily have to be specified across multiple planning levels, reducing the number of planning levels to be included could also be an option in other countries – especially for RAAs, given the tight approval deadlines under Article 16a(1) RED.

However, the duration of relevant spatial planning procedures should also be scrutinized. A survey (BMWSB 2022, 11), revealed an alarming average duration of 5.3 years for updating regional plans on wind energy / renewable energies (BMWSB 2022, 20). This is partially due to the preparation and updating of environmental reports and especially the repetition of consultations necessary in the case of fundamental amendments to draft plans (Section 9(3) ROG) (BMWSB 2022, 16). Priebs (2023, 11) speaks of possible never-ending loops. Planning authorities may even refrain from spatially or environmentally sensible (but not inevitable) changes to drafts to avoid further rounds of participation.

Another topic in this context is that the pressure to consider (dynamically changing) environmental aspects in depth and with high-quality data in spatial planning on renewables is likely to increase in the EU with the new concept of RAAs (including requirements on tools, datasets, and mitigation measures) and the corresponding rules in Article 16a RED.[27] This makes it even more difficult to quickly finish planning procedures.

The EU should therefore consider clearly ruling – by amending the SEAD – that no further participation is required (but voluntarily possible) under Article 6(2) SEAD after initial participation, if no more than, for example, 5% of the area for OWT or GM-PV is added or removed during a draft revision (alternatively limited to RAAs). However, this should be made dependent on the environmental report being updated for the corresponding areas before the final decision on the plan or programme.[28] Section 9(3) ROG should then be amended accordingly. This would be in line with Article 7 of the Aarhus Convention that does not require renewed participation.

Furthermore, in view of the dynamics in nature and possible new information from participation, the directive should be amended to clarify that pure modifications to environmental reports – including new factual information[29] – do not trigger a mandatory requirement for new participation in plans that define zones for OWT or GM-PV (or in general). SEA in this urgent action requiring field should primarily serve to improve the knowledge of democratically legitimated decision-makers rather than the participation rights of third parties.

As a precaution, the scope of such amendments of EU regulations could be limited in time, and their effects monitored.

4.6. Economic framework conditions

Designating areas can only have a full effect if flanked by fitting economic framework conditions. The approach of Section 36 h EEG, which uses correction factors to ensure different site qualities for wind energy utilisation is partially compensated for, thus is positive – if combined with sufficient tender volumes and adequate remuneration levels – and of great importance given the limited spatial potential for wind energy in Germany. It might be an option in other countries with similar conditions as well.

Unfortunately, however, there is no such mechanism for PV in Germany to date. A corresponding equalization in the EEG should therefore be introduced for rooftop PV and GM-PV – also to avoid excessive profits in irradiation-rich areas. Within the EU such future regulations have to be reviewed on the basis of Articles 107 and 108 of the Treaty on the Functioning of the European Union (TFEU), but experience with Section 36 h EEG shows that such mechanisms are accepted if they do not unduly distort economic competition.[30] This can be incorporated into both auction-based and administratively set support schemes. Most MS use at least one of these schemes, so the approach should be transferable (CEER 2023a, 12–14, CEER 2023b).

Remuneration should be based on a reference yield (in tender systems calculated after surcharge) for an average site and adjusted up or down for regional differences in global irradiation and resulting yields, similar to 36 h EEG. However, adjustments should be uniform across larger regions to maintain incentives to develop the best intra-regional projects and to keep the administrative burden low.

Moreover, there are further possibilities to promote greater self-sufficiency – and possible additional goals. These include sub-regional tendering volumes for GM-PV in line with desired spatial priorities. Likewise, allocated regional grid access for GM-PV systems could be auctioned to better capture and spatially steer freely financed installations – given the large potential areas for GM-PV (Section 4.2). In this context, also grid capacities or aspects like regional land degradation could be considered (von Seht 2023, 191–193) and, again, within the EU the TFEU rules must be taken into account.

In the case of Germany, such regulations might flank or even be, to a limited extent, an alternative to the currently discussed (Dobos, Bichler, and Knörr 2025, 1–3) introduction of different pricing zones. They could contribute to limiting costs – at best, in combination with regulations on a sensible spatial allocation of new large storage facilities, nets and similar infrastructure. This corresponds to recommendations for a better spatial coordination in a recent German monitoring report on the energy transition (EWI, BET 2025, 180–185).

5. Discussion and conclusion

The dynamics of climate change and the pressing geopolitical challenges require – referring to the wording and theoretical analysis of Næss (2023, 2345–2346) – a content-driven optimization of the planning-related framework conditions for the expansion of OWT and GM-PV systems in Germany. It is about increasing quantity and speed, but also about spatially appropriate and plannable arrangements of renewable energy technologies regarding the overall energy system. In this, Olesen can be followed who argues – like considerations of Gailing et al. (2025, 441–442) on rational approaches – that planning must be intensified 'in a time of multiple crisis' (Olesen 2023, 2323). The current regulations in Germany entail already corresponding positive and innovative elements – also in terms of planning theory.

This refers mainly to the new system centred around MATs that, regarding zoning, mostly relies on regional planning. It can be seen as an effective rational meta-regulation (Einig 2011, 190–194) through statutory targets and procedural streamlining which – where applicable – also reduces the complexity of regional OWT planning and makes local planning on it dispensable. It ensures adequate and sufficiently fairly distributed designated areas for OWT in a democratic and – at least regarding locations – in practice still comprehensive participation (Gailing et al. 2025, 439) entailing process that has a key starting point in sophisticated analysis on national potentials. At the same time, the approach takes into account, by reducing the requirement for the involvement of different levels, that there may be tension between comprehensive involvement and the need for rapid transformation (Skjølsvold and Coenen 2021, 2; Hofer and Kaufmann 2023, 368). In governance terms, this constitutes hierarchical framing within a polycentric system: lower tiers retain implementation responsibilities, but the scope for discretion is limited – and inaction is sanctioned.

If the signs of success (Rheinschmitt and Köck 2023, 1395; Schlacke, Plate, and Thierjung 2025, 446; Gailing et al. 2025, 434–437) become more apparent, the new system can also be seen as demonstrating, that it is possible to make use of the advantages of rational top-down planning approaches (Pissourios 2014, 89–94) regarding coordination, speed and goal-orientation while still allowing – given the remaining decision-making latitude – for meaningful agonistic debates that 'make people powerful and masterful' (Pløger 2004, 87).

Furthermore, the new regulatory regime for OWT can, in line with Schlacke, Plate, and Thierjung (2025, 446), even be understood as inadvertently reviving the steering capacity of supra-local, cross-sectoral spatial planning – thus aligning with broader trends across most European countries towards stronger integration of sectoral policies in spatial planning (Nadin et al. 2021, 796–797).

More systematic, the analysis, has demonstrated that planning and authorisation for OWT and GM-PV energy expansion in Germany takes place as part of a complex multi-level regulatory system which especially with the EEG und WindBG goes beyond the framework of planning in the narrower sense (von Seht 2024, 56). This regulatory system consists – based on Einig (2008, 22–23) – partly of external control by the public sector over private actors and partly of internal control within the public sector. It contains classic elements of regulatory policy (Czada and Lütz 2003, 15), such as goals, rules, monitoring of compliance, and sanctions. By elaborating on the past and current regulatory framework for OWT, it has been shown that optimizing such a complex interaction can be a key factor in strengthening the expansion of renewables.

These findings should be used to address identified shortcomings in Germany, particularly in the spatial coordination of GM-PV. Thus, a comprehensive regulatory approach with, inter alia, MATs for GM-PV is suggested (Section 4), which relies on spatial planning for zoning and includes supportive economic framework conditions.

Generally, the recommended regulatory provisions are aimed at taking safety aspects into account that deserve greater attention in Europe. Increasing spatially relevant threats – similarly emphasized in ARL (2025) – must be considered in regulations for OWT and GM-PV – especially regarding spatial planning. This is because accelerated and adapted spatial planning that takes the different production patterns of both technologies into account can enhance resilience. A resulting more secure power supply based on renewable energies for defence facilities and arms production – possibly as storage-supported microgrids capable of islanding – can even form part of a deterrence policy.

Crucial to this is timely support for decentralization and partial regional energy autonomy to mitigate the potential negative consequences that would result especially from attacks on power lines. This applies not only to the spatial distribution of OWT and

GM-PV, but also to technologies necessary to meet the – partially manageable – energy demand despite fluctuating electricity generation from renewable energies, such as storage systems or, where unavoidable, decentral hydrogen-compatible gas-fired power stations.

As MATs, the accelerating regulatory proposals regarding SEA would also shift the focus more towards ‘contents and consequences’ (Næss 2023, 2346), but only moderately reducing the weight of public involvement. This is balanced because delay can severely impact urgent needs as climate protection (von Seht 2024, 58), while involvement remains vital for acceptance and acquiring information.

Many theoretical findings of this study are of general nature and many recommendations made can likely be implemented in other European countries or beyond, provided that the conditions and problems relevant to the different proposals are similar to those in Germany. To some extent this has already been elaborated as part of Section 4. However, in addition, it should be emphasized that most European countries are subject to the same relevant EU regulations, aim to foster the same renewables with often similar schemes (CEER 2023a, 2023b) and share a common electricity market, enhancing the chances of transferability. Furthermore, many countries face comparable geostrategic risks or spatial structures and, in some cases, similar conditions regarding radiation and wind resource. The proposals regarding SEA are even European in nature as they address the SEAD.

A closer examination of how transferable the takeaways are to other countries could be a promising avenue for further, future-oriented research. Regarding Europe, valuable additional foundations are provided by Dupré la Tour (2023) on potential, Pickering, Lombardi, and Pfenninger (2022) on technical options or Wingenbach et al. (2024) and Bartoszewicz-Burczy (2022) on regulatory frameworks.

Notes

1. Directive (EU) 2018/2001 of 11.12.2018 (OJ L 328, 21.12.2018, p. 82-209), http://data.europa.eu/eli/dir/2018/2001/oj.
2. Directive (EU) 2023/2413 of 18.10.2023 (OJ L, 2023/2413, 31.10.2023), http://data.europa.eu/eli/dir/2023/2413/oj.
3. The term refers to timing and process (Gurreck 2025, 90–91).
4. https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20241219-3#:~:text=In%202023%2C%2024.5%25%20of%20gross,pp%20from%202024%20to%202030 (11.02.2026).
5. Directive 2001/42/EC of 27 June 2001 (OJ L 197, 21.7.2001, p. 30-37), http://data.europa.eu/eli/dir/2001/42/oj.
6. Directive 2011/92/EU of 13.12.2011 (OJ L 26, 28.1.2012, p. 1-21), http://data.europa.eu/eli/dir/2011/92/oj.
7. Council Directive 92/43/EEC of 21.05.1992 (OJ L 206, 22.7.1992, p. 7-50), http://data.europa.eu/eli/dir/1992/43/oj.
8. Erneuerbare-Energien-Gesetz of 21.07.2014 (BGBl. I p. 1066; last amended by Article 23 Act of 18.12.2025, BGBl. 2025 I No. 347).
9. Data, also for other countries: https://map.neweuropeanwindatlas.eu/ (11.02.2026); https://globalwindatlas.info/en/ (11.02.2026).
10. Data, also for other countries: https://globalsolaratlas.info/map?c=47.353711,7.646484,5&s=53.094024,0.131836&m=site (11.02.2026).
11. Baugesetzbuch in the version published on 3.11.2017 (BGBl. I p. 3634; last amended by Article 5 Act of 22.12.2025, BGBl. 2025 I Nr. 348).

12. Windenergieflächenbedarfsgesetz of 20.07.2022 (BGBl. I p. 1353; last amended by Article 4 Act of 12.08.2025, BGBl. 2025 I No. 189).
13. Gesetz zur Erhöhung und Beschleunigung des Ausbaus von Windenergieanlagen an Land of 28.07.2022 (BGBl. I p. 1353).
14. Raumordnungsgesetz of 22.08.2022 (BGBl. I p. 2986; last amended by Article 7 Act of 12.08.2025, BGBl. 2025 I No. 189).
15. Classic systems are land-intensive and place modules close to the ground. Other options are agri-PV (high agricultural use) or floating PV.
16. https://globalsolaratlas.info/map?c=50.492463,6.28418,6 (11.02.2026).
17. There was already an exceedance in 2024 (https://climate.copernicus.eu/copernicus-2024-first-year-exceed-15degc-above-pre-industrial-level (11.02.2026)).
18. In Europe, 2024 was 2.92 degrees above the average for 1850–1900 (https://climate.copernicus.eu/global-climate-highlights-2024 (11.02.2026)).
19. Understood here as energy being reliable available and affordable (Colgan, Gard-Murray, and Hinthorn 2023, 1).
20. Nevertheless, measures against drones and similar devices may become necessary.
21. Particularly risky are nuclear plants in this respect.
22. Here understood as in UN (2016, 22). Central is to absorb shocks and bounce back efficiently without losing core functions.
23. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52025JC0009 (11.02.2026). Onshore, locating faults in and repairing underground high-voltage cables is particularly critical.
24. See notes 12 and 13 on data radiation and wind speeds for all European countries.
25. See, for example, Elsner, Collaer, and Uihlein (2026, 30–53) on different distances to residential areas for OWT potential in European countries.
26. See von Seht (2021, 616–617) regarding former legal debates and a solution – like Section 249(1) BauGB.
27. See e.g. demands by Wingenbach et al. (2024, 74).
28. For the national legal situation see Section 9(3) ROG, a decision of HessVGH of 25.01.2018 (4 B 1535/17.N) and the judgement of OVG SWG of 20.01.2015 (1 KN 7/13).
29. A ruling of the German Federal Administrative Court (BVerwG) of 8.03.2017 (4 CN 1/16) addressed restructuring of environmental reports, but the consequences of adding relevant information remain unclear.
30. European Commission, Decision of 21 December 2022, State Aid SA.102084 (2022/N) – Germany – Renewable Energy Act 2023.

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