JRC141683

European Commission

SCIENCE FOR POLICY BRIEF

How to implement locational criteria in renewable auctions

A practical guide

HIGHLIGHTS

→ Introducing locational criteria to renewable auctions leads to more renewable energy integrated into the grid, less redispatch and lower consumer costs.

→ The impact of location can be evaluated using standard modelling tools: A grid modelling exercise is sufficient to derive the system contribution of a given renewable project. Points can then be awarded by grouping candidate projects based on their benefit to the system.

→ To ensure a robust evaluation of the locational criterion, the grid modelling exercise should ideally take place at European level, cover several decades of climate data, as well as a time span that considers the entire lifetime of the assets in question.

→ Transparency and competition are key to maximize the benefits from locational renewable auctions. Calculated locational impact should be published early, before the auction takes place. In this way project developers know where to build to win the auction. At the same time, this ensures that renewables are being developed where they benefit the system most.

Joint Research Centre

CONTEXT

The Implementing Regulation of Article 26 of the Net Zero Industry Act[1] (NZIA) features provisions to assess the locational impact of a renewable project in an auction. Aside from applying quotas for certain regions, location can be included as a non-price criterion, awarding points based on the impact on the electricity system. This can reward projects that would reduce congestion in the grid, leading to lower grid expansion costs and a higher utilization rate of the renewable capacity to be installed.

The Implementing Regulation further specifies the relevance of modelling tools to assess the energy system integration benefit associated with constructing a certain renewable project in a given location. This brief presents a *"how to"* guide *to determine the locational benefit of renewable energy projects with the help of a grid modelling exercise*. We start by shedding light on the potential benefits that locational renewable auctions could bring to the European system, before moving on to a detailed description of the methodology to derive the locational impact of renewable projects with the help of grid modelling.

The results presented here are taken from two scientific articles, which are published as preprints alongside this brief.

IMPACT OF LOCATIONAL AUCTION DESIGN

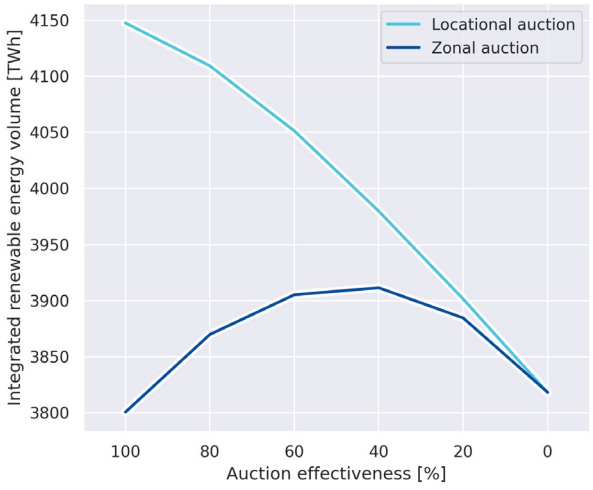
The results presented in this section are based (Thomaßen and Fuhrmanek, 2025). This case study compares a renewable auction model with locational component (locational auction) with a classical auction which does not differentiate based on location. To approximate realistic distributions, the outcome is assessed with a varying effectiveness of the auction process[2]. It has to be stated that a very high auction efficiency, close to 100% is hardly realistic, as this would imply that project developers built *only* in those locations that are most competitive in the auction process. This is unrealistic with highly distributed generation technologies, such as wind and solar photovoltaics (PV), as their developments depend on a range of other factors, such as local administrations, competition for area from other purposes or a strongly varying cost of land.

The degree to which an auction achieves system optimal deployment depends therefore not only on the auction design, but as well on other factors, for example, on how competitive the auction process is. Only if there exists a large-enough number of projects to pick from, a locational auction design can select those at better locations over those which would exacerbate grid congestion. Likewise, if an auction is undersubscribed, (close to) all projects will receive a remuneration contract, irrespective of any locational incentive. Lastly, (close-to-)optimal deployment will depend on project developers actually developing renewables in those areas that are most beneficial to the system.

Renewable Integration

Our results show that the amount of renewables integrated into the system highly depends on where they are being deployed (**Figure 1**). A highly effective auction process maximizes the benefits that can be attained by locational auction design. This highlights the importance of competitive auctions, with a large pool of projects to pick from.

Figure 1: Total renewable energy volumes integrated into the European system in 2040



Source: (Thomaßen and Fuhrmanek, 2025)

[1] Non-price criteria for renewable energy auctions

[2] We define auction effectiveness as the degree to which an auction mechanism will incentivize deployment in those locations which are most competitive *in the respective auction mechanism*. Research has shown that renewable deployment does not only take place in those locations which are most competitive, which, in a conventional auction, would be those sites with the highest capacity factors (Rahmad et al., 2025).

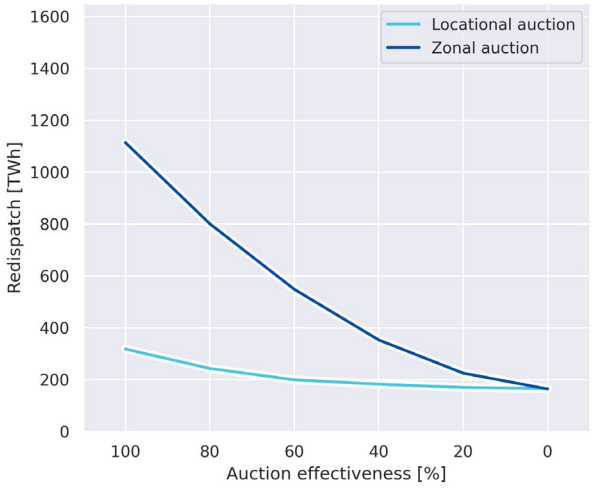
The conventional zonal auction mechanism, however, performs worst if the auction is highly competitive[3]. Under these circumstances, deployment occurs primarily in *resource-rich areas*, where projects are most competitive due to high capacity factors. A large share of renewable generation, however, ends up being curtailed due to grid congestion.

Redispatch

The volume of remedial actions necessary to correct the market outcome after the market clearing (redispatch) are further highly dependent on the auction mechanism in place. Steering capacity to locations beneficial to the grid might not be sufficient to avoid all redispatch, yet will help keeping the necessary amount at bay.

The zonal auction design, on the other hand, produces much higher volumes of redispatch (**Figure 2**). This is again driven by deployment that focusses primarily on resource rich areas, while grid infrastructure to transmit the generated energy to consumers is not taken into consideration.

Figure 2: Total redispatch volumes in the European system in 2040



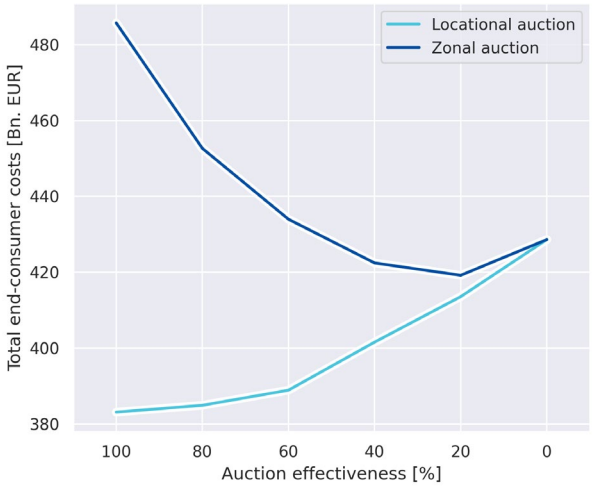
Source: (Thomaßen and Fuhrmanek, 2025)

Consumer costs

To assess the impact of auction design on the final consumer, we evaluated all payments in the wholesale market, as well as the cost of redispatch.

We can see a substantial consumer benefit for as long as the auction's design has *any* effect on renewable deployment. While it is difficult to pinpoint the exact consumer benefit – since auction effectiveness is hard to measure – savings in the tens of billions of EUR appear realistic. This, in turn, highlights the importance not only of implementing locational criteria in auctions but also of adopting measures to increase the effectiveness of the auction, which is further discussed in the section that addresses best practices.

Figure 3: Total end-consumer cost in the European system in 2040.



Source: (Thomaßen and Fuhrmanek, 2025)

HOW TO EVALUATE LOCATIONAL CRITERIA?

This section describes how locational criteria can be evaluated by applying a grid model to determine the system benefit of deploying different renewable technologies in various grid locations, and converting it into an index with the help of a point system. The latter step is necessary for an evaluation within the framework of non-price criteria in a multi-criteria auction. A detailed description of the method presented in this section can be found in (Thomaßen, 2025).

In a perfect nodal market[4], the value of any renewable energy project to the system would be accurately captured by its market value. An auction would produce system-optimal deployment, as those projects that are most beneficial to the system would also have the highest market value. We can use this to derive locational price signals, which, if applied in a conventional auction process, would achieve the same

[3] With an auction efficiency of 100%.

[4] With perfect foresight, risk-neutral investors and capturing the entire grid topology.

deployment as an auction in a perfect nodal market would.

The underlying concept is that the locational price signal must represent the difference in profitability between a project under the current market rules and in a market with perfect nodal pricing. This can be achieved by first removing the wholesale market impact on a project's profitability under the current market design, which is represented by its *market value*. In a second step, one can add the *system value* of the project, which is represented by the market value in a perfect nodal market.

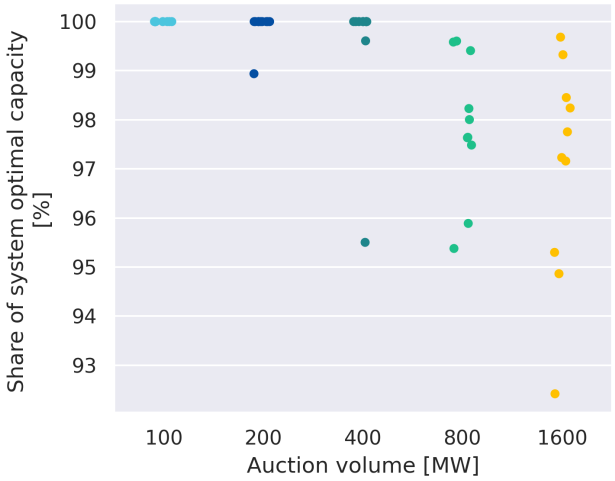
The mathematical proof can be found in (Thomaßen, 2025). At the same time, the rationale makes sense intuitively: If one wants to incentivize investment as it would occur in a perfect nodal market, one needs to remove the impact of the existing market design on the investment decision (the market value), and add the financial impact that a perfect nodal market would have.

Deviations from system-optimal deployment remain, due to the fact that projects within one auction round impact each other's market and system value. These impacts can, however, only be taken into consideration *after* each round of auctions, when the locational price signals are recalculated.

We have shown that this approach generates close-to-optimal outcomes, which exceed the performance of a conventional auction process by far. To this aim, we modelled the deployment under ten rounds of auctions – once with and once without locational price signals – and evaluated how much capacity was deployed in a location that was optimal from a system perspective.

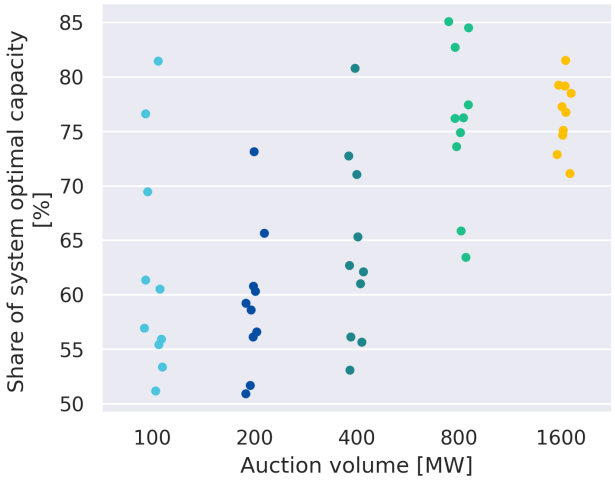
Figure 4 and **Figure 5** show the share achieved in each round of auction for different auction volumes. One can see that the locational auction achieves much higher shares of system optimal allocation – exceeding 92% in each case – than the conventional auction mechanism. Over several auction rounds, the locational auction was further found to increase system costs at a much lower rate (compared to fully system-optimal deployment).

Figure 4: Share of system optimal capacity in the locational auction



Source: (Thomaßen, 2025)

Figure 5: Share of system optimal capacity in the conventional auction

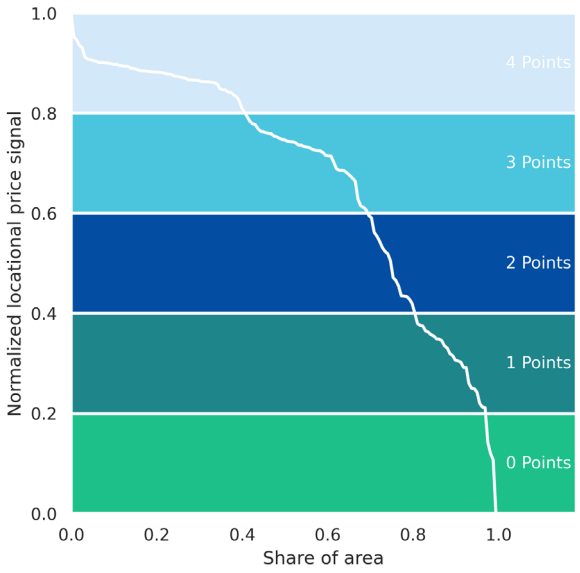


Source: (Thomaßen, 2025)

Deriving a scoring system for a locational criterion

We can convert the locational price signals to points, so that they can be awarded in an auction setting that is in line with the provisions featured in the Implementing Regulation.

Figure 6: Points awarded for locational criterion based on normalized locational price signals. Sorted from highest locational price signal to lowest.



Source: (Thomaßen, 2025)

To this aim, we can normalize the locational price signals and rank them from highest to lowest. The normalized distribution can then be divided into equidistant intervals which reflect the total number of points that should be awarded (**Figure 6**).

Based on this scoring system, a map can be created which visualizes which area in a given Member State is best suited for renewable deployment. This would allow project developers to focus their efforts on those regions that achieve the highest points – and therefore the highest benefit to the system.

BEST PRACTICES

— **Climate and scenario data.** To ensure a robust evaluation of each project's location, a large set of climate years and target years should be considered in the modelling exercise. By considering decades of climate years – similar to the European Resource Adequacy Assessment – one can ensure that the locational evaluation considers a broad range of weather realisations. From a technical perspective, weather datasets with the necessary geographical and temporal coverage are readily available (such as ERA5). Open source tools can convert these into renewable availability timeseries[5]. The future outlook should at least consider the full remuneration period of the assets tendered, potentially even the entire lifetime as the asset will likely remain in the system for this period. In addition, sensitivity to changes in fuel prices and ETS price could be assessed to increase robustness against unforeseen changes.

— **Grid modelling exercise**. The most complex part of the methodology presented here is the grid modelling exercise, which forms the basis for the evaluation of the locational criterion. To get started, it could be reasonable to task the respective TSO(s) in each Member State to conduct this exercise, as the necessary data is available to them. The geographical coverage should at least cover the entire capacity calculation region, if not the entire European system. In the medium to long term, it would be reasonable to switch to a coordinated grid modelling exercise for the whole European system. On the one hand, this would minimize the modelling effort to derive the locational value of capacity. On the other, it would ensure that these values are consistent between Member States. Further, it would facilitate broad stakeholder involvement.

BLUEPRINT FOR A LOCATIONAL RENEWABLE AUCTION

1. Create a scenario for the future development of the European electricity system **which covers ideally the entire lifetime of the technologies participating in the auction.**
2. Run both a grid and a market model for large set of climate years and over the full scenario horizon. **Determine market and system values and derive the locational price signals for each participating technology at each grid connection point.**
3. Convert locational price signals to a scoring system, assigning points. **This includes deriving the number of points awarded per location, but as well the value of a single point.**
4. Publish maps for each technology **which indicate the points awarded for connecting to a certain grid connection point.**
5. Hold the auction and award points to submitted projects based on their location in the grid.

[5] See, for example https://atlite.readthedocs.io/.

- **How often to evaluate locational impact?** To achieve deployment that is as close as possible to system optimal deployment, it is necessary to update the locational adders regularly. Ideally, this would take place after each round of auctions. Especially with a large coordinated grid modelling exercise, this might not be feasible. An update that takes place at least each year would, however, be highly recommendable.
- **Increasing the effectiveness of locational auctions.** Transparent publication of the calculated locational impact is key. Before each round of auctions, the locational value of capacity should be published, to ensure that project developers are aware where the best sites for winning the auction are located. This does not only improve their prospects but ensures further that deployment focusses on the most beneficial areas. In addition, our results have stressed the importance of a highly competitive auction. It remains therefore important to speed up permitting procedures and to ensure that enough land is available for renewable development. Only if the volume offered in the auction is large enough, a good location can offer a real advantage to auction participants.

CONCLUDING REMARKS

This Science for Policy Brief presents a practical guide how to implement a locational criterion within renewable auctions – in line with the Implementing Regulation of Article 26 of NZIA – and details the benefits that can be achieved. In doing so, it summarizes the findings of two scientific articles (Thomaßen, 2025; Thomaßen and Fuhrmanek, 2025), one of which is currently under review.

Our results show that a locational criterion can increase the amount of renewables integrated into the grid, reduce the necessary redispatch measures, while lowering consumer bills. In practice, a locational price signal can be calculated through a grid modelling exercise, determining the value to the system of a given renewable installation, as well as its market value. These price signals can further be converted into a point scale, which enables the inclusion of a locational criterion within a multi-criteria auction which non-price criteria.

The introduction of a locational criterion within European renewable auctions can be facilitated by establishing a coordinated grid modelling exercise, covering the whole European electricity system. Locational impact should be assessed regularly, to ensure an accurate evaluation within auction processes, and consider a large range of climate data and future scenario years. Maximizing the benefits of locational auction design further hinges on holding highly competitive auctions. Speeding up permitting procedures and ensuring that sufficient land is available for renewable deployment remains therefore essential.

REFERENCES

Rahmad, Y., Hedenus, F., Jewell, J., Vinichenko, V.,2025. Spatial heterogeneity in deployment and upscaling of wind power in Swedish municipalities. Renewable and Sustainable Energy Transition 7, 100104. https://doi.org/10.1016/j.rset.2025.100104

Thomaßen, G., 2025. Introducing locational criteria to renewable auctions. [submitted manuscript].

Thomaßen, G., Fuhrmanek, A., 2025. Where to build renewables in Europe? The benefits of locational auction design. Energy Economics 147, 108579. https://doi.org/10.1016/j.eneco.2025.108579

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