SPATIAL CLUSTERING OF RENEWABLE TIMESERIES FOR REGION GENERATION IN EUROPEAN ELECTRICITY EXPANSION PLANNING MODELS

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Overview

The European power system is undergoing a decarbonisation process, as part of the broader quest to achieve a climate neutral Europe by 2050. This process is leading to an increasing share of intermittent Renewable Energy Sources (iRES) in the energy mix. More than ever, planning models play a crucial role in achieving the decarbonisation targets at minimal cost.

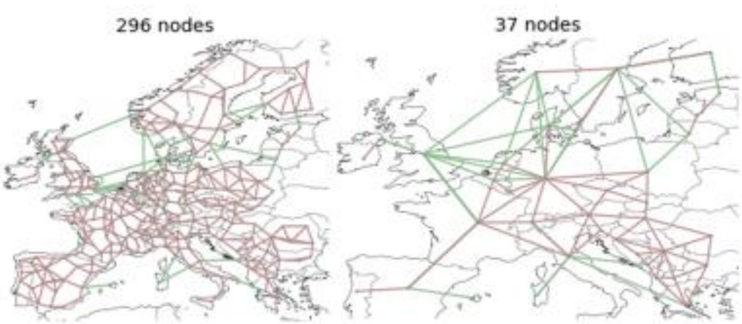
Scientific literature shows that this integration leads to an increasing need for cooperation over large areas [1], which can be most efficiently optimized together in expansion planning models [2]. One of the main reasons for this is the geographical smoothing of renewable time-series. In addition, fine spatial detail is desired for spatially explicit planning models [2,3]. As such, both transmission bottlenecks and optimal locations for renewable power plants can be easily identified, thus increasing the accuracy of the estimated total cost.

However, solving the combined transmission and generation expansion planning problem is a computationally demanding task. Doing so at a high level of spatial detail and for a large geographic region quickly becomes computationally infeasible. Therefore, this research aims to answer the question of how a low spatial resolution can be maintained to ensure computational feasibility, whilst limiting the loss of information regarding locations for renewable power plants and transmission bottlenecks.

Outstanding literature on the importance of spatial resolution [1] highlights two concurring effects of spatial resolution reduction on obtained system cost in planning models. Loss of best locations for renewable plants will lead to overestimation, while the lack of identification of transmission bottlenecks will lead to underestimation. Little attention is given to how this loss of information can be tackled.

Methods

A potential solution can be found in improving the way modelled regions are generated. Many expansion planning models, including the one used in [3], start from administrative regions, notably countries. From a renewable power plant perspective, this does not necessarily make sense since the homogeneity of renewable power plants is not ensured within countries. As proposed in [4], the use of spatial clustering techniques can be used to generate alternative regions, which do ensure homogeneity of renewable power plants within model regions.



High- and low resolution system visualization for the conventional country-based approach. Each node in the system represents its surrounding region and has a time-series for demand and renewable generation. Results from the optimization contain installed capacities per node, as well as line investments. The goal of this work is to intelligently construct the regions that are represented by one node.

This research aims to combine the benefits of the open-source pypsa-eur model used in [3], with spatial clustering techniques used in [4], to analyse whether the alternative way of region generation can improve the accuracy of low resolution models. Specifically, this study combines the accurate representation (and reduction method) of the transmission network, embedded in pypsa-eur, with spatial clustering techniques.

Low resolution solutions of both this new strategy and the country based approach are benchmarked against a high-resolution solution.

Results

Moving away from the country based approach is expected to improve the accuracy of low resolution models. By using clustering techniques, relatively few regions can be used whilst still ensuring homogeneity within them. Therefore, doing so based on renewable time-series is expected to largely eliminate the observed loss of information regarding best locations for renewable plants within large spatial regions.

Furthermore, transmission bottlenecks arise to a large extent in highly renewable systems because power from intermittent generation centers has to be transported to load centers. When (at least) a single network node is used for each renewable region –as opposed to a single node per country-, prominent power flows are expected to become apparent more easily in low resolution models.

Conclusions

We conclude that in the development of spatially explicit planning models for highly renewable energy systems, countries are not necessarily the ideal basis for spatial-explicitness. It makes sense to disregard political boundaries in early planning stages, and focus more on the homogeneity of renewable technologies to construct model regions.

Future work can be aimed at further improvement of the low-resolution approximations by considering multiple already existing clustering techniques, such as k-means, and max-p. Furthermore, clustering based on multiple time-series attributes can be studied (other than the average capacity factors over extended time horizons), such as variability, and correlation with demand. Finally, methods to combine regions from different clusterings can be constructed.

References

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