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Using Global Wind Speed and Solar Insolation Data together with Resource Based Slicing to Capture the Intermittency of Variable Renewables

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1 – Aim

The share of wind and solar based electricity production is expected to grow significantly in coming decades due to lowered costs as well as policy incentives fuelled by climate and energy security concerns. Thus it has become increasingly important to account for their variability in energy system models that are used to explore long term developments. However, the scope of these models often prohibits the use of a high intra-annual time resolution that could adequately capture the main characteristics of variable renewables. A more efficient representation is required.

We demonstrate how freely available global wind speed and solar insolation data can be used to derive resource availability based temporal groups called slices and show that a low number of such slices can capture many effects caused by intermittency of variable renewables in large scale energy system models.

2 – Methodology

To estimate the resource potential and capacity factors of wind and solar technologies, datasets of wind speeds and solar insolation for 2013-2015 were used. Several auxiliary datasets were utilised to exclude areas where solar and wind power cannot be placed. After masking out unsuitable locations, a certain fraction of the remaining area is considered available for solar and wind farms. We estimate potentials for on- and off-shore wind, rooftop PV, PV plants and CSP plants with 12 hour storage.

Next, each three-hour time step in each model region was allocated to one of the groups that combines hours with similar characteristics – a slice. The allocation was based on the output of “representative time series” for solar PV and wind power, which are calculated by assuming that PV panels and wind turbines are distributed evenly throughout each region in all grid cells with above average solar or wind resources.

The slices were then implemented in the GET model. GET is a cost minimising “bottom-up” systems engineering model of the global energy system set up as a linear programming problem. The model was developed to study carbon mitigation strategies with an objective of minimising the discounted total energy system cost for the period under study (in general 2000–2100) while meeting both a specified energy demand and a carbon constraint. The model focuses on the supply side and has five end use sectors: electricity, transport, feedstock, residential–commercial heat and industrial process heat. GET has a single demand node for each of its 10 regions and thus the electricity grid is not explicitly modelled.

We explored the effect of implementing resource based slices in the GET model as well as effect of the number of slices employed to the model results.

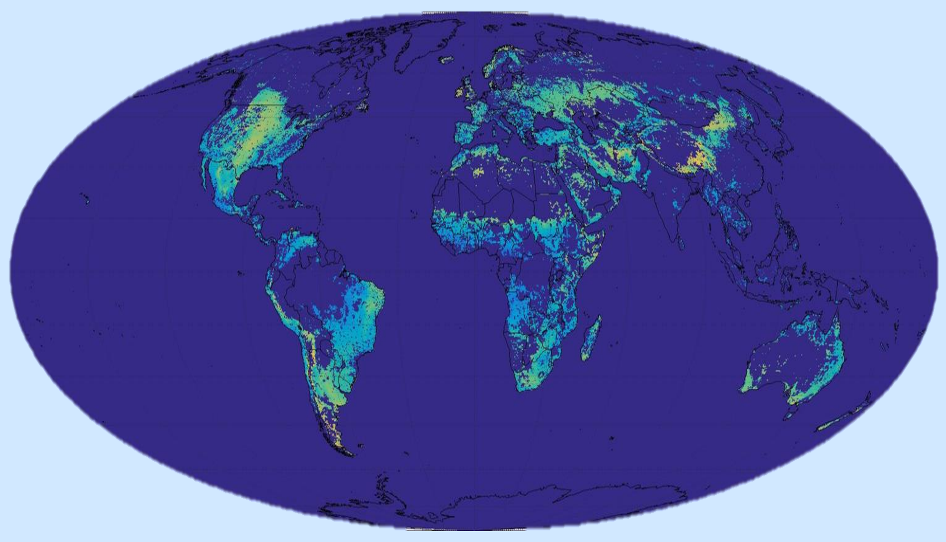

Figure 1. Example of data filtering: suitable areas for onshore wind.

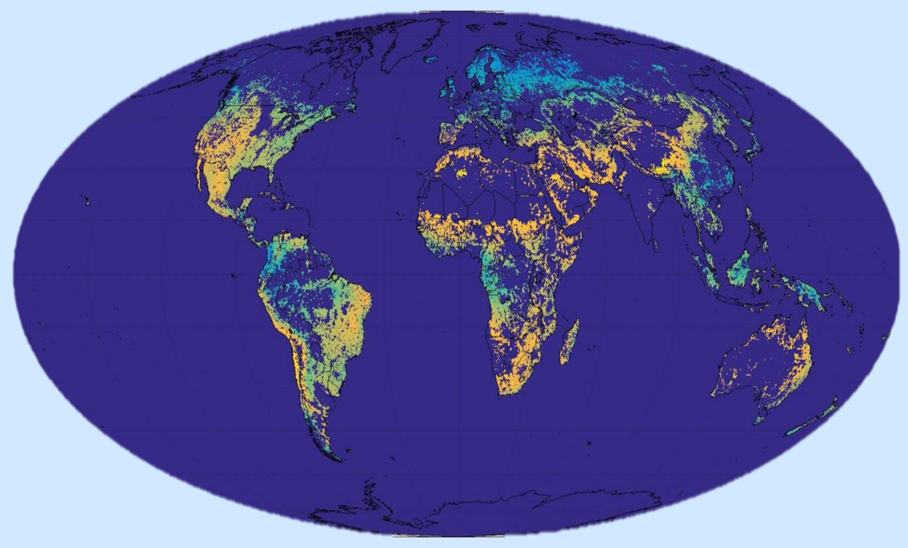

Figure 2. Example of data filtering: suitable areas for PV plant.

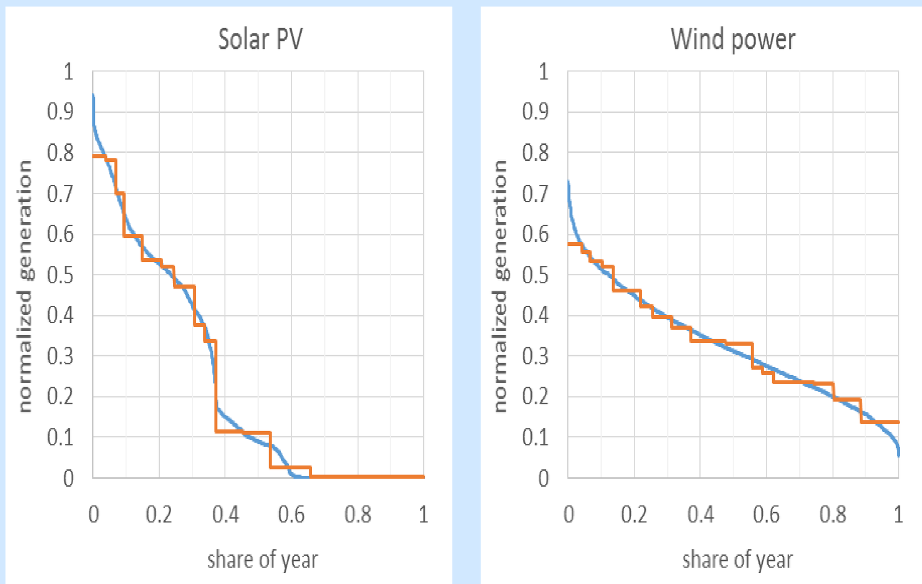

Figure 3. Normalised duration curves of the representative time series for solar PV and wind power in Europe (blue) and sorted average output of the 16 individual slices (orange).

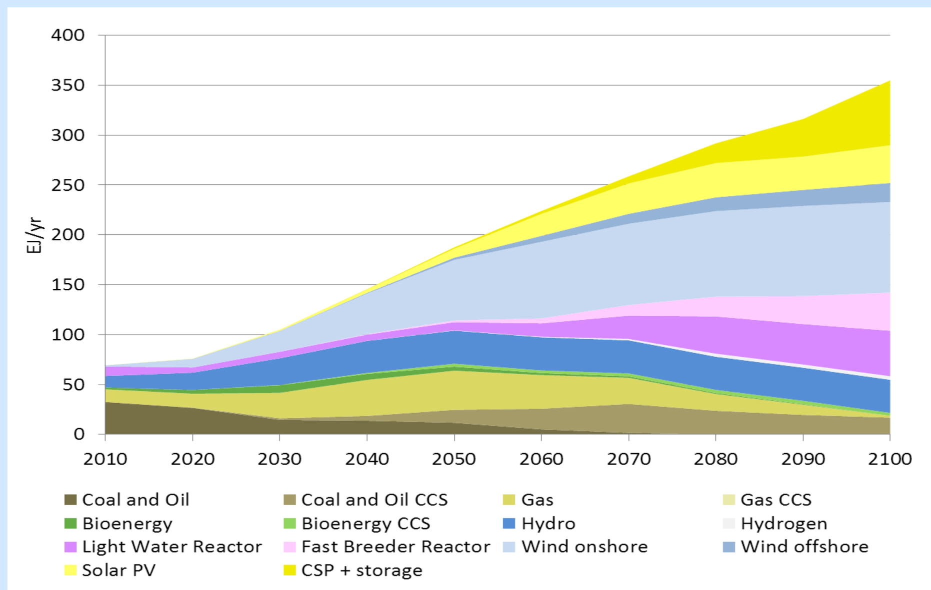

Figure 4. Global electricity production in a scenario meeting the 450 ppm concentration target.

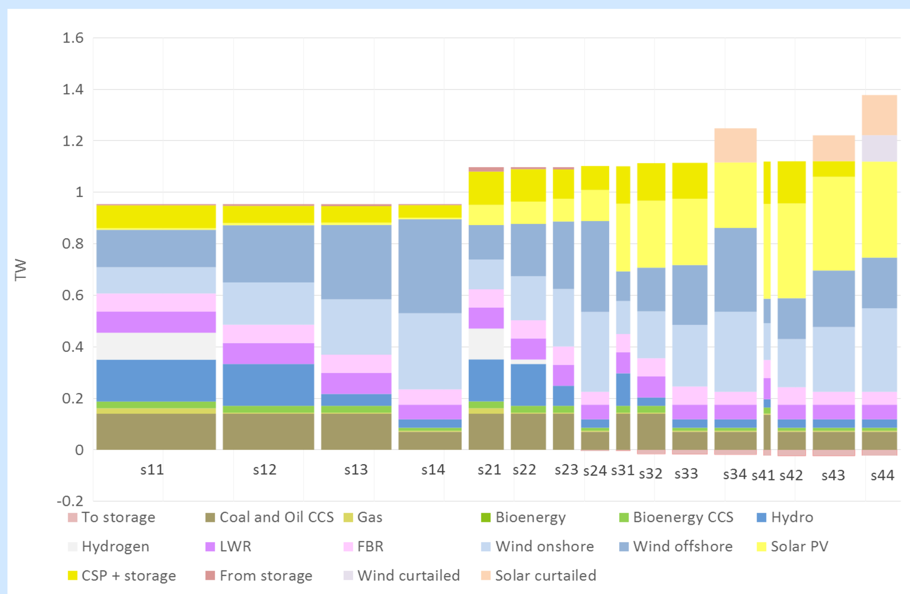

Figure 5. Sliced electricity production in Europe in year the 2100 in a scenario meeting the 450 ppm concentration target.

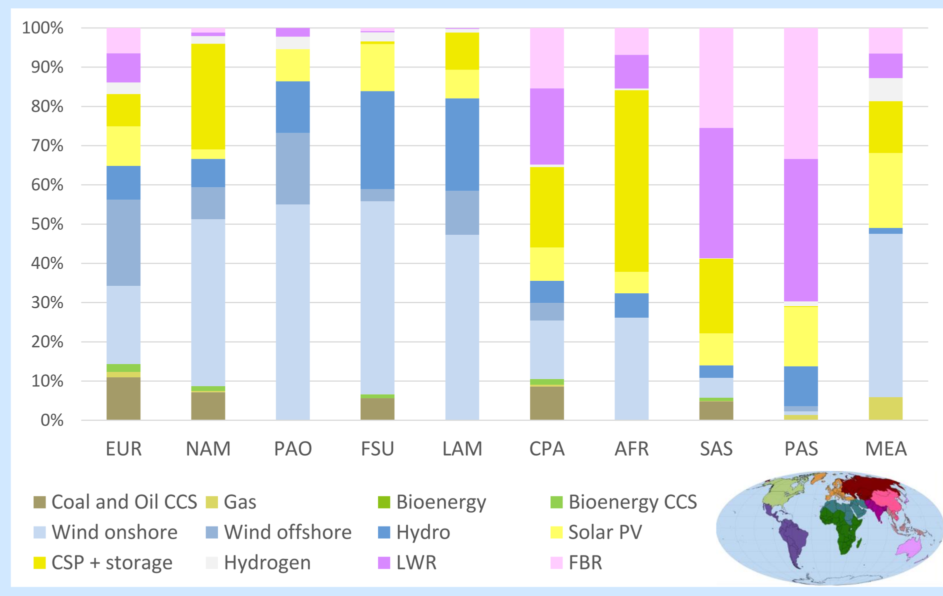

Figure 6. Regional aggregated electricity production at 2100 in a scenario meeting the 450 ppm concentration target.

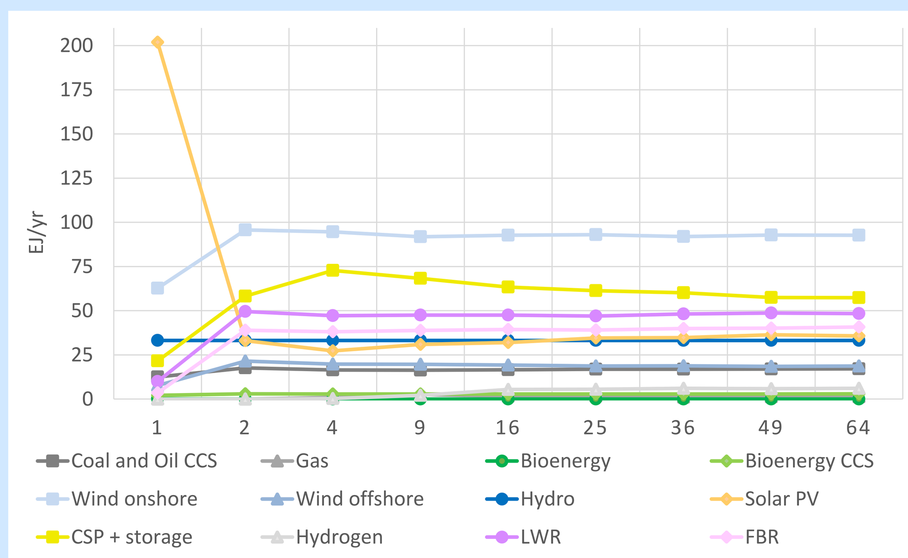

Figure 7. Global electricity mix in the year 2100 for different number of slices in a scenario meeting the 450 ppm concentration target.

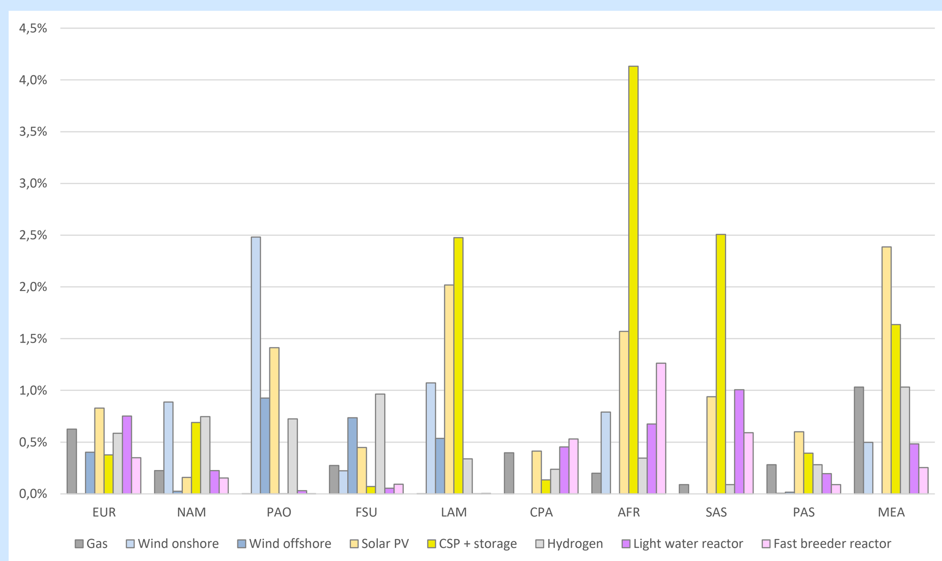

Figure 8. Standard deviation of electricity generation of main technologies relative to regional demand in the results with 9 to 64 slices.

3 – Conclusions

- Resource-based slicing captures the three main drivers of profile costs:
  - a low capacity credit for variable renewables and resulting requirements for firm capacity, as demonstrated by low wind and solar resource slices where other technologies than variable renewables need to be invested in e.g. gas turbines or hydrogen.
  - reduced utilisation of dispatchable plants as demonstrated by high wind and solar resource slices where dispatchable capacity is down regulated.
  - occasional overproduction of variable generation resulting in curtailment.
- Optimal electricity production mixes vary significantly among regions due to different endowments of solar and wind resources.
- About 16 slices can capture a large share of the intermittency introduced by variable renewables.
- Assumptions made while masking out unsuitable locations and fraction of the remaining area considered available for solar and wind farms play a substantial role in resulting resource potentials for given technology.

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