Description of pre-project (Spring 2023)

Student name: Oskar Sidor and Thea Gorzelak

Title: **Climate change impact on wind, solar, hydropower and heating demand.**

Project duration: 2 students x 10 ECTS = 20 ECTS = 10 person-weeks.
Start date: End date:

Future energy systems with high renewable penetration will be more sensitive to changes in weather patterns induced by climate change. In recent work, the impact of climate change on hydropower operation has been investigated [1]. In this pre-project, the impact of climate change on wind, solar, hydropower and heating demand will be investigated.

WP1. (2 weeks) Literature review
The students will read the relevant scientific articles on the topic. A recommended list will be provided by the supervisors. This WP will run in parallel to the others.

WP2. (2 person-weeks) Model solar, wind and hydro time series under different climate change scenarios using Atlite

This work package (WP) includes the creation of time series representing the solar, wind and hydro generation for every country in Europe at the Beginning of the Century (BOC) and End of the Century (EOC) for different climate models included in the 6th Coupled Model Intercomparison Project (CMIP6) [2]. Obtain wind, solar, and hydro time series for the 15 GCMs included in [4,5].

For solar, optimal tilted PV modules will be considered, for wind 5MW wind turbines will be considered. Capacity layouts should be (a) proportional to wind/solar resource and (b) uniform. ~~will be assumed.~~

This WP includes also the time devoted by the student to: (a) learn how to use Atlite [3], (b) learn how to download CIMP6 data [4], and (c) learn how to use the PRIME cluster.

The students will have access to the scripts from a previous MSc project which will serve as a basis for their pre-project. This WP includes the statistical analysis of the interannual variability and intermodal variability and their comparison with differences seen between the BOC and EOC periods.

WP3. (2 person-week) Validation of BOC time series with historical data

For BOC, annually averaged capacity factors for wind and solar will be calculated from the modelled time series and compared to historical values (based on the historical electricity generation and installed capacity) to validate the time series, see e.g. [4].

The modelled time series at the BOC obtained from different climate models will be validated by comparing them with historical time series. The specific metrics to be used for the validation will be agreed among the students and the supervisors on the first meeting and might include: (i) Annual capacity factors validation with historical values obtained from IRENA statistics on installed capacity and annual generated energy, (ii) comparison of seasonal average values (winter, spring, summer, autumn), (iii) comparison of monthly values, (iv) duration curves, (v) distribution of ramps. Evaluate the time series (climate models at BOC and

ERA5, and historical -ENTSOE-) using the metrics shown in Figure 2 in ref [3]: PDF, CDF, time autocorrelation function, and spatial correlation. Using figure 5 (seasonal) and Figure 8 (mean changes and uncertainty, dots indicating where there is no good agreement among models) in [4].

WP4. (2 person-week) Model heating demand time series under different climate change scenarios using Atlite

Similarly to WP2, time series for heating demand will be produced for different climate models and validated.
This WP includes the statistical analysis of the interannual variability and intermodal variability and their comparison with differences seen between the BOC and EOC periods.

WP5. (2 weeks) Running PyPSA-Eur-Sec with network representation of Europe
In preparation to using PyPSA-Eur-Sec[5] in the master project, the students will devote time to install and learn by themselves how to run the model in the cluster and will try to make it run for different weather years.

Remark 1: This pre-project will be co-supervised by the PhD student Ebbe K. Gøtske, who will help the master student with the selection of climate models in WP1, the use of the cluster and the interpretation of the results.
Remark 2: This pre-project can be naturally continued into a master-thesis project.

[1] EK. Gøtske and M. Victoria, Future operation of hydropower in Europe under high renewable penetration and climate change, iScience 24(9) 102999, (2021) https://doi.org/10.1016/j.isci.2021.102999
[2] https://www.wcrp-climate.org/wgcm-cmip
[3] https://atlite.readthedocs.io/en/latest/
[4] https://github.com/PyPSA/atlite/blob/master/examples/historic-comparison-germany.ipynb
[5] https://pypsa-eur-sec.readthedocs.io/en/latest/

RECOMMENDED LECTURES FOR WP1

[1] Ebbe K. Gøtske and M. Victoria, Future operation of hydropower in Europe under high renewable penetration and climate change, iScience 24(9) 102999, (2021) https://doi.org/10.1016/j.isci.2021.102999

[2] Schlott, Markus & Kies, Alexander & Brown, Tom & Schramm, Stefan & Greiner, Martin, 2018. "The impact of climate change on a cost-optimal highly renewable European electricity network," Applied Energy, Elsevier, vol. 230(C), pages 1645-1659. https://doi.org/10.1016/j.apenergy.2018.09.084

[3] Evaluating the mesoscale spatio-temporal variability in simulated wind speed time series over northern Europe, Gabriela Luzia et al. 2022, https://doi.org/10.5194/wes-7-2255-2022

[4] Current and future wind energy resources in the North Sea according to CMIP6 by Hamman et al, 2022 https://wes.copernicus.org/articles/7/2373/2022/

[5] Wind energy resource over Europe under CMIP6 future climate projections: What changes from CMIP5 to CMIP6, Carvalho 2021, https://doi.org/10.1016/j.rser.2021.111594