REQUEST FOR A SPECIAL PROJECT 2019–2021

MEMBER STATE: The Netherlands

Principal Investigator: Karin van der Wiel

Affiliation: KNMI (Royal Netherlands Meteorological Institute)

Address: Utrechtseweg 297
Postbus 201, 3730 AE De Bilt
The Netherlands

Other researchers: Frank Selten (KNMI)

Project Title: European energy transition: energy security in a highly-renewable system

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2019	
Would you accept support for 1 year only, if necessary?	YES	

Computer resources required for 2019-2021: (To make changes to an existing project please submit an amended version of the original form.)		**2019**	**2020**	**2021**
High Performance Computing Facility	(SBU)	30,000,000	0	0
Accumulated data storage (total archive volume)[2]	(GB)	40,000	0	0

Continue overleaf

Principal Investigator: Karin van der Wiel

Project Title: European energy transition: energy security in a highly-renewable system

Extended abstract

Scientific background

To mitigate anthropogenic climate change a global energy transition from fossil fuels to renewable energy is needed. Within Europe, the European Union (EU) works to promote clean energy targets and support individual nations in their transition. Current EU legislation includes a binding target of 20% of total energy consumption from renewables in 2020, increasing to at least 32% in 2030(1). Furthermore, Europe is working towards a fully connected internal energy market to enable the redistribution of energy over the full European grid.

The transition towards a future with a larger share of renewable energy comes with challenges. One such challenge is the variability of renewable energy production caused by the variability of the weather. To achieve grid stability (i.e. constant voltage and frequency) and energy security (i.e. the uninterrupted availability of energy sources at an affordable price(2)) during periods of low renewable energy production, energy must be provided by other sources. Some options include (i) using energy storage solutions to accumulate energy over time, (ii) connecting a large spatial grid to transport energy from regions with high production, or (iii) increased energy production from back up power plants, e.g. nuclear, biomass, fossil fuels. Further complicating the transition is the variability of energy demand, which is highly dependent on temperature. Potential coincident periods of low production and high demand may lead to energy shortage and put societies at risk.

The temporal-spatial variability of renewable energy production and energy demand, and consequently potential energy shortage, is in part determined by meteorological conditions. Our work at KNMI aims to contribute to the ongoing European energy transition with insights from a meteorological perspective. Based on an existing EC-Earth large ensemble experiment (2000 years, present-day climate) we have calculated 2000 years of renewable energy production (from wind and solar PV sources) and energy demand over an European domain. These estimates were then used to determine the meteorological conditions giving rise to potential disruptions in energy supply.

For a European fully-connected electrical grid, the lowest energy production events occur in winter under large-scale high pressure conditions (due to low wind conditions and low incoming solar radiation), see the composite map in Fig. 1a. Potential energy shortage events are caused by a comparable high pressure system, though accompanied by a large-scale cold anomaly (Fig. 1b). In both situations, transporting energy from other regions (solution 2 above) is not feasible as there are no regions with energy production surplus in the European domain (taken here to be EU13+2).

During these high-impact events, either solution 1 (storage) or 3 (other sources) must therefore match the demand of energy. Storage options require excess energy to be available in the days preceding the event, energy from backup plants require these to be started or production to be scaled-up. Both solutions would benefit from advance knowledge, i.e. predictability, of the upcoming high-impact events. Given the dependence on meteorology for both energy production and energy demand, there is potential for predictability of high-impact events in the European energy sector.

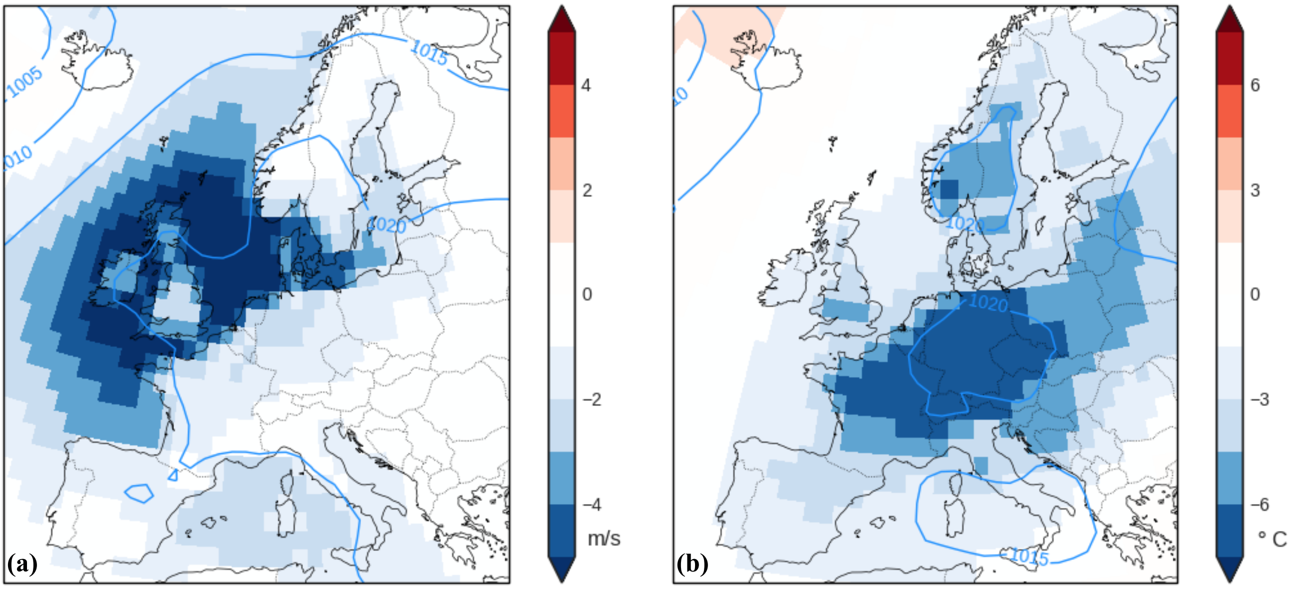

Figure 1. Composite maps for **(a)** 1-in-10 year low renewable energy production events and **(b)** 1-in-10 year high potential energy shortage events. Contour lines show sea level pressure [hPa], shaded colours in (a) show 10 m wind speed anomalies [m/s] and in (b) 2 m temperature anomalies [°C].

For this reason, we would like to extend the ongoing project with a work package in which the potential predictability of high-impact events for the European energy sector is investigated. The first part of our proposed special project aims to provide us with the computer resource needed to do so. Given the importance of grid stability and energy security this is of high societal relevance and contributes towards KNMI's ambition to develop an Early Warning Centre.

The second aim of our proposed project is to investigate whether these high-impact events will be influenced by climate change. Projections of changes in near-surface wind and cloudiness show little to no change. However, extreme events may respond differently than the mean, especially given potential changes in atmospheric dynamics and variability of weather. The large-scale high pressure systems leading to extreme low renewable energy production or potential energy shortage (Fig. 1) may be subject to change. Possible changes we are interested in investigating include the frequency of occurrence (do we expect more/less high-impact events) and the persistence of events (longer periods of low production/high demand requires larger storage systems or larger energy production back-up systems). For the summer season, it has been shown that increasing waviness of the jetstream leads to more persistent high pressure systems[3]. Understanding of the impact of global warming on high-impact events for the energy sector can contribute to creating better designs for a stable and secure future European energy supply.

Scientific questions

Using the computer resources in this special project we aim to address two topics: the potential predictability of high-impact energy events and the impact of projected climate change on high-impact energy events.

[*Potential predictability*] What is the potential predictability for high-impact energy events? Predictability is evaluated for three types of events:

1. Extreme low European renewable energy production (wind and solar PV)
2. Extreme high European energy demand (temperature driven)

If low production and high demand occur simultaneously, there is a risk of energy shortage. We plan to also investigate the compounding effects and predictability of potential shortage:

3. Extreme high European energy shortage

[Climate change] How does projected climate change impact the occurrence and persistence of high-impact energy events?

1. Extreme low European renewable energy production
2. Extreme high European energy demand
3. Extreme high European energy shortage

This proposed special project is part of a larger project, which aims to improve scientific understanding of the meteorological origin of events of extreme societal impact. Societal risk is the result of complex, non-linear interactions between the physical environment and societal factors. Whether extreme meteorological conditions lead to extreme societal impacts depends on more than just the weather. Therefore, we base the selection of events on a measure of societal impact (amount of energy produced, total energy demand, potential energy shortage). This allows us to investigate the meteorological origin of these high-impact events and provides higher accuracy for estimates of risk(4).

Planned experiments

This special project extends ongoing work at KNMI on the topic of European energy security. We have previously run two large ensembles (2*2000 years) with EC-Earth v2.3(5) at the ECMWF facility. The two lines of research outlined above each spin off from these existing ensembles.

[Potential predictability] High-impact events have been selected and investigated in the existing present-day ensemble. For some of these events we plan to do short-term prediction experiments, to determine potential predictability under the assumption of a perfect model and a perfect knowledge of the initial condition. Longer lead times for warnings are of high relevance to both energy production companies and transmission system operators responsible for the uninterrupted supply of energy.

These experiments can only be ran on the ECMWF system, as it is a requirement of predictability experiments that the events of interest can be reproduced exactly. A test on 6 June 2018 has confirmed that despite system updates since 2016 we can still create exact reproductions. We will run prediction experiments for the 10 highest impact events (for production, demand and shortage extremes), at lead times varying from 2-28 days. We will run 50 ensemble members which will be created by choosing different seeds in the stochastic physics parameterisation. Total expected computer time is approximately 1000 model years = 10 MSBU. Storage requirements are limited as only a few variables need to be saved, totalling approximately 10 TB.

[Climate change] We plan to run a third large ensemble with 3 °C global warming. This ensemble will complement the two existing EC-Earth ensembles (present-day and 2 °C-warming) and three HadGEM2-ES model ensembles created using the exact same protocol (present-day, 2 °C-warming and 3 °C-warming). The created large ensemble will also be used for other climate impact studies than what is described in this special project application.

The new ensemble consists of 2000 model years = 20 MSBU. Given other applications for the data we plan to store the same variables as for the original ensembles, requiring a total of 30 TB.

Technical details

We run the global coupled climate model EC-Earth, version 2.3(5) (CMIP5 version). It is based on IFS cycle31R2 at T159 resolution with 38 vertical levels, NEMO/LIM at 1° resolution and 42 levels in the vertical and the OASIS coupler.

The estimates of required SBUs are based on the SBUs used to create the existing EC-Earth large ensembles (ECMWF UID nkkw, years 2016-17, ran 2*2000 years: 39,437 kSBU).

References

[1] European Commission statement 18/4155 (http://europa.eu/rapid/press-release_STATEMENT-18-4155_en.htm, accessed 18 June 2018)

[2] International Energy Agency (https://www.iea.org/topics/energysecurity/whatisenergysecurity/, accessed 18 June 2018)

[3] Coumou, D., Petoukhov, V., Rahmstorf, S., Petri, S. and Schellnhuber, H., 2014. Quasi-resonant circulation regimes and hemispheric synchronization of extreme weather in boreal summer. Proceedings of the National Academy of Sciences, 111, pp.12331-12336.

[4] Van der Wiel, K., Selten, F., Bintanja, R., Blackport, R. Screen, J., 2018. Extreme impacts from moderate meteorological conditions: the benefits of ensemble climate impact modelling. Undergoing peer-review.

[5] Hazeleger, W., Wang, X., Severijns, C., Ştefănescu, S., Bintanja, R., Sterl, A., Wyser, K., Semmler, T., Yang, S., van den Hurk, B., van Noije, T., van der Linden, E., van der Wiel, K., 2012. EC-Earth V2.2: description and validation of a new seamless earth system prediction model. Climate Dynamics, 39, pp. 2611-2629.