Compound climate events WP2

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SusRenew kick-off meeting

Sogndal

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Definition compound events

1. Two or more extreme (weather) events occurring simultaneously or successively
2. Combinations of extreme events with underlying conditions that amplify the impact of the events
3. Combinations of events that are not themselves extremes but lead to an extreme event or impact when combined.

Source: IPCC SREX Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, 2012

In other words

“Compound events are weather and climate events that result from multiple hazards or drivers with the potential to cause severe socio-economic impacts. Compared with isolated hazards, the multiple hazards/drivers associated with compound events can lead to higher economic losses and death tolls.” (Ridder et al., 2020)

Examples:

Temperature and drought: Summers in Europe (2003, 2018), Russia (2010), or California (2014)

Consecutive storms: October 2014 flood western Norway, Mozambique 2019

Wind and precipitation: Mozambique 2019, Dagmar 2011, hurricane Sandy 2012

Storm surge and precipitation: Bryggen in Bergen 2005, 2017, hurricane Sandy 2012

Global hotspots

Study by Ridder et al., 2020

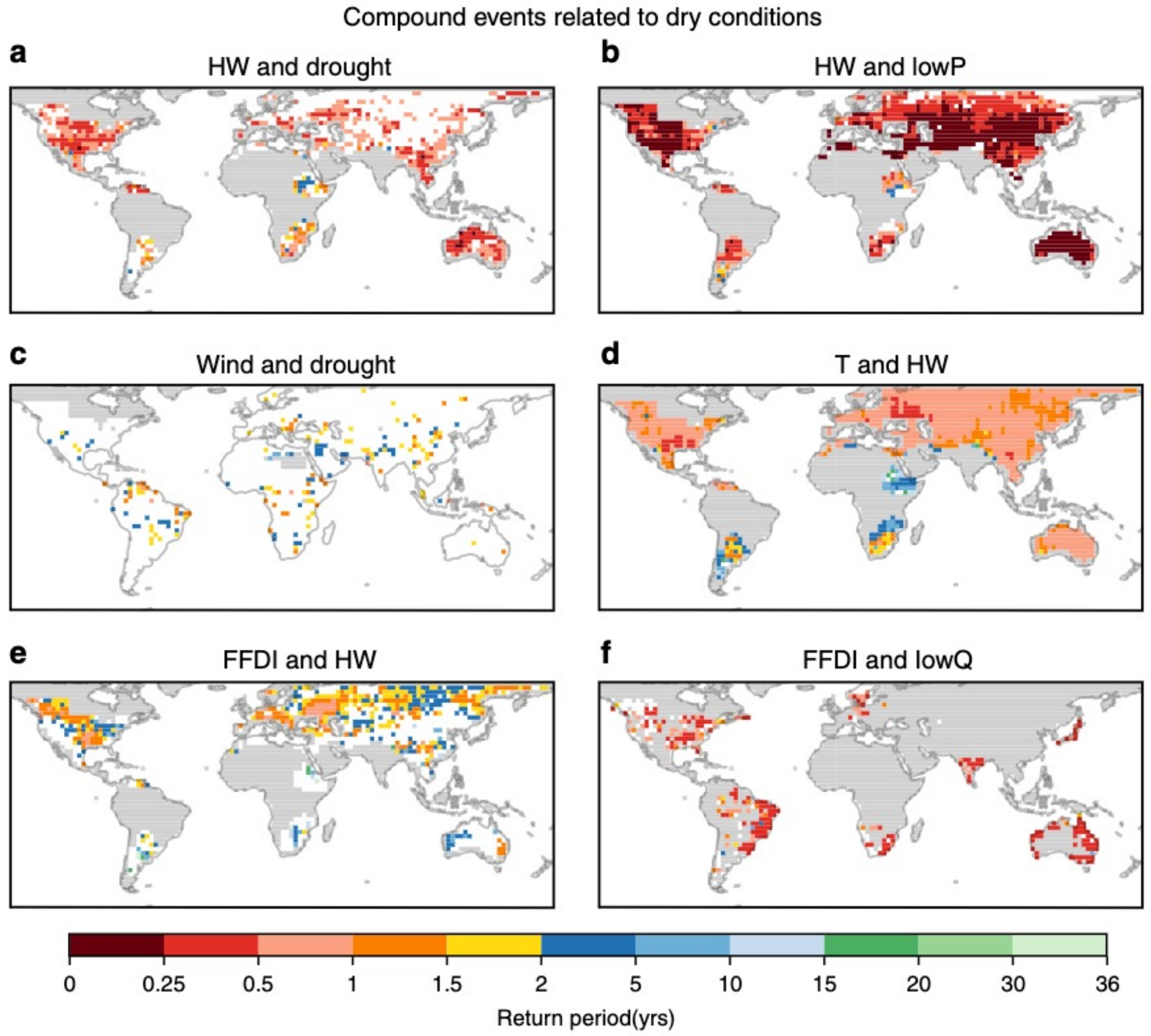

Fig. 1 Hotspots of joint occurrence of different hazard pairs related to dry conditions. This includes meteorological drought (drought) and hydrological drought (lowQ) in combination with heatwaves (HW), extreme temperature (T), McArthur forest fire danger index (FFDI), and low streamflow (lowQ). Shown are CEs consisting of **a** heatwave and meteorological drought, **b** heatwave and hydrological drought, **c** strong winds and meteorological drought, **d** high temperatures and heatwaves, **e** high fire danger and heatwave, and **f** high fire danger and hydrological drought. Joint occurrences are given as RP of the actual probabilities derived from the data allowing the direct comparison of different panels, and to Fig. 2 and Supplementary Fig. 1. Only statistically significant values are shown ($p \leq 0.05$); statistically insignificant values are masked (white). Grey areas indicate regions without data coverage (Supplementary Fig. 10), or where percentile values of at least one hazard falls below the minimum required percentile value (Supplementary Table 2).

So far, research has focused on joint occurrence of different hazard pairs at the same geographical location, e.g., wind and drought (Ridder et al., 2020).

SusRenew will expand on this research in two ways:

- Identify climate hazards that are specifically relevant for the energy system,
- Calculate the joint probability of hazard pairs in different geographical sites that are linked together in the energy system.

Such links can be of various kinds, and in the research on transboundary risks at least four ‘pathways of risks’ - are identified: People, trade, finance, and biophysical (Hedlund et al., 2018).

Example: Cross-border power cables. The situation in 2021 of reduced precipitation in Norway, resulting in reduced filling of the hydropower reservoirs, and little wind over major wind-energy producing areas of Europe.

Relevant for SusRenew

From Otero et al., 2022:

Energy compound events - periods of simultaneous low renewable production of wind and solar power and high electricity demand

Assess spatial coherence of energy compound events that pose a major challenge within the interconnected power grid as they can affect mutiple countries simultaneously.

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Meteorological Applications

RESEARCH ARTICLE

Characterizing renewable energy compound events across Europe using a logistic regression-based approach

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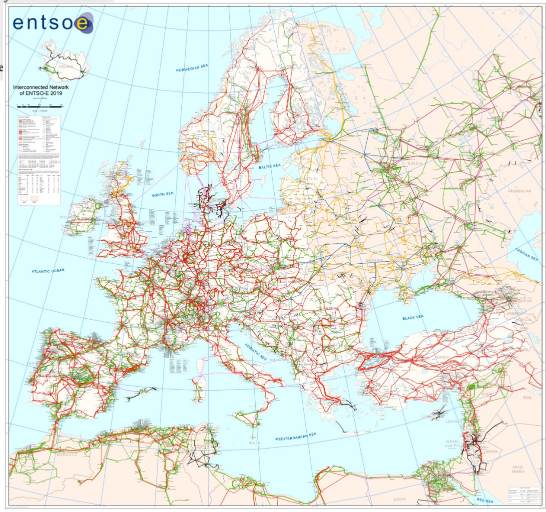
Abstract
The transition towards decarbonized power systems requires accounting for the impacts of the climate variability and climate change on renewable energy sources. With the growing share of wind and solar power in the European power system and their strong weather dependence, balancing the energy demand and supply becomes a great challenge. We characterize energy compound events, defined as periods of simultaneous low renewable production of wind and solar power, and high electricity demand. Using a logistic regression approach, we examine the influence of meteorological and atmospheric drivers on energy compound events. Moreover, we assess the spatial coherence of energy compound events that pose a major challenge within an interconnected power grid, as they can affect multiple countries simultaneously. On average, European countries are exposed to winter energy compound events more than twice per year. The combination of extremely low temperatures and low wind speeds is associated with a higher probability of occurrence of energy compound events. Furthermore, we show that blocked weather regimes have a major influence on energy compound events. In particular, Greenland and European blocking lead to widespread energy compound events that affect multiple countries at the same time. Our results highlight the relevance of weather regimes resulting in synchronous spatial energy compound events, which might pose a greater risk within a potential fully interconnected European grid.

KEYWORDS
energy compound events, extremes, renewable energies, weather regime



https://www.entsoe.eu/data/map/

From Otero et al., 2022

Europe is exposed to winter energy compund events more than twice a year

–> combination of (extremely) low temperatures and low wind speeds (blocking situations)

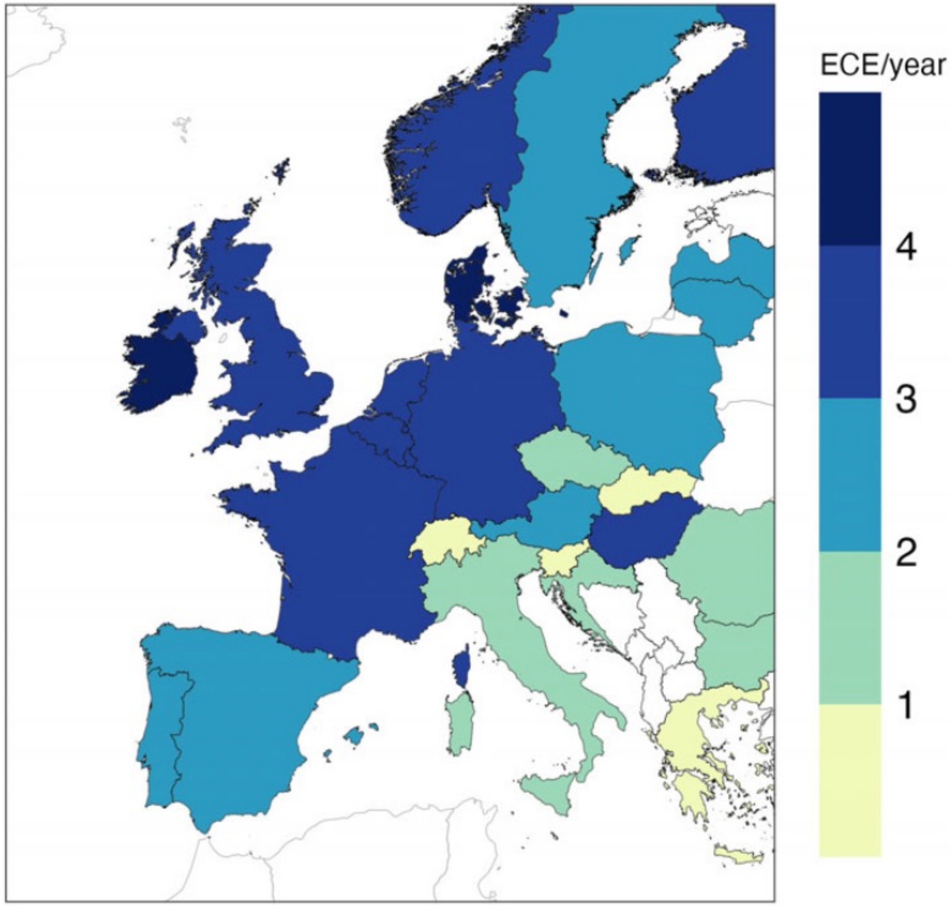


FIGURE 1 Observed frequency of occurrence (per year) of energy compound events (ECEs) for each country over the period of study 1979–2019.

What are the most important climate hazards contributing to climate risks of a future renewable energy system?

- Identify weather regimes (e.g., Grams et al., 2017) used in Otero et al., 2022
- Assess to what extent impact events may change in the future, spatial and temporal data describing past, present, and future climate is needed. SusRenew will use the state-of-the-art global and regional climate model data simulating the European climate and tailored for Norway (ERA5, CMIP6, Euro-CORDEX, KiN2100)
- Weather regimes ('drivers') potentially generating various climate hazards will be projected with a likelihood describing spatial and temporal exposure.
- Emphasis will be put on understanding the probability of compound events, which may pose a large risk to the renewable energy system. Here we will develop tools to detect and analyse the effect such combined hazard events may have on the energy system.

WP2 outline

T. 2.1

Workshop with all user representatives discussing stage 1 (“scoping”) of the Impact Chain framework (WNRI, NORCE)

T. 2.2

Establishing the knowledge basis for presenting climate-related information for the energy system for year 2050 and 2100 (NORCE)

T. 2.3

Developing tools to assess compound-events in present and future climate conditions and the impact on energy production (NORCE)

Goal

- Acquire new knowledge on potential cross boundary compound and local climate hazards that can trigger climate risks relating to the energy system.
- Identify and describe the climate hazards that are most relevant for assessing climate risks of the energy system to serve as input to WP3.

Output

- popular report in Norwegian (NORCE, WNRI)
- research article on future transboundary compound climate hazards that relevant for the renewable energy system (NORCE)

References

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NOU 2023: 3 Mer av alt – raskere — Energikommisjonens rapport Kap. 8

A simple example

INDEPENDENT EVENTS

- What is the probability of a die that is rolled twice landing on 6 both times?
- Each time the die is rolled, it constitutes an independent event, so the outcome of the roll of a die does not affect the outcome of subsequent rolls. Given that P(A) is the probability of the first roll landing on 6, and P(B) is the probability of the second roll landing on 6:
- $P(A \text{ and } B) = P(A) \cdot P(B) = 1/6 \times 1/6 = 1/36 = 0.0278$
- There is approximately a 2.78% chance of a fair die landing on 6 both times in 2 rolls.

Dependent events

- The probability of a compound event where the events are dependent events can be found by first calculating the probability of the first event, then calculating the probability of the second event occurring given that the first has already occurred (the conditional probability of the second event given the first).
- Multiplying the probability of the first event by the conditional probability of the second event, given the first, results in the probability of both events occurring:
- **$P(A \text{ and } B) = P(A) \cdot P(B|A)$**

Probability of dependent events

As an example, assume that 20% of the students in a high school are seniors and that 40% of students in the high school have taken pre-calculus. If being a senior had no effect on whether or not a student had taken pre-calculus, then the probability of being a senior and having taken pre-calculus would be (0.20)·(0.40) = 0.08. However, if it is observed that being a senior increases the probability that a student has taken pre-calculus to 65%, the above probability would be incorrect. The 40% chance of a high school student having taken pre-calculus would need to be adjusted to take into account that a senior is more likely to have taken the course.

The probability that a student is both a senior and has taken pre-calculus is therefore the probability of a student being a senior multiplied by the probability of the student having taken pre-calculus given that they are a senior:

$$P(\text{senior and pre-calculus}) = P(\text{senior}) \cdot P(\text{pre-calculus} \mid \text{senior}) = (0.20) \cdot (0.65) = 0.13$$

Therefore, there is actually a 13% chance that a student is both a senior and has taken pre-calculus, rather than an 8% chance, since the latter doesn't take into account the increased probability of having taken pre-calculus by the time the student is a senior.