

Introducing weather situations affecting the

renewable energy system

Stephanie Mayer

OSLO, DECEMBER 3RD 2024



IPCC SREX, 2012, Chap. 3: compound events can be

. . .



https://climateextremes.org.au/what-is-a-compound-event-in-weather-and-climate/

- two or more extreme events occurring simultaneously or successively,
- combinations of extreme events with underlying conditions that amplify the impact of the events, or
- combinations of events that are not themselves extremes but lead to an extreme event or impact when combined.

Seneviratne, S.I., N. Nicholls, D. Easterling, C.M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi, M. Reichstein, A. Sorteberg, C. Vera, and X. Zhang, 2012: Changes in climate extremes and their impacts on the natural physical environment. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 109-230.

Renewable energy compound events

Europe is exposed to winter energy compound 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.

| | | Time | | |
|-------|--------------------|--|--|---|
| | | Full overlap | Partial overlap | Subsequential |
| Space | Full overlap | storm with extreme rainfall amount coinciding with (extreme) high tide at the same time at the same place | extreme precipitation falling as snow which during the day gradually turns into rain and melting of snow due to an increase in temperature | long period of drought followed by an extreme precipitation incident |
| | Partial overlap | extreme precipitation that simultaneously affects large parts of a catchment area and creates an increasing flood situation down the river course (e.g., Hans incident) | extreme precipitation that begins at the top of a catchment area and moves downwards along the river course | several atmospheric rivers hitting partially the same region over a couple of weeks |
| | paired | Dunkelflaute (little wind and solar power) | little wind in the UK (reducing wind power production) and at the same time drought in Norway (reducing hydro power production) causing high energy prices | spring-drought in Norway, followed by late summer low winds in the UK, creating disruptions in electricity prices |

NVE is starting to explore compound events, too:

The combination of increased electrification, a greater share of weatherdependent power production and covariation in weather types will continue to weaken the Nordic power balance, and power can become a significant scarcity factor in periods of low wind and extreme cold.



too little or too much water

Drought and concurrent doldrum leading into a cold winter 2021/2022



N R C E

https://www.nve.no/energi/analyser-og-statistikk/magasinstatistikk/

Historiske strømpriser

Strømprisen i dag er 27 % lavere enn siste 28 dager 👻

Strømrekorden i Oslo var **tirsdag 30. august 2022**. Da var gjennomsnittsprisen **645,26 øre** for én kWh (uten nettleie, avgifter og mva).



Extreme weather 'Hans'

- August 2023
- well predicted
- unusually high rainfall amounts
- flood
- Brassereidfoss dam broke
- more rainfall came shortly after



Extreme weather 'Hans' – august 2023

- atmospheric river from the east
- total moisture uptake from soil and vegetation



Betydningen av atmosfæriske elver for ekstremnedbør i Norge. Kartet til venstre viser prosentandelen av ekstreme nedbørhendelser som kan kobles til atmosfæriske elver. Kartet til høyre viser sesongen der ekstremnedbør i forbindelse med atmosfæriske elver er mest vanlig. SON = september-november, DJF = desember-februar, MAM = mars-mai, JJA = juniaugust. Utsnitt fra figur 4 i Michel et al., 2021 under lisens CC-BY.



Extreme weather 'Hans' – August 2023

- unusual storm track,
- infrastructure not built to handle such large amounts of water (> 150 mm/48h)
- soil was saturated with water after the first storm and the water was then not absorbed by the soil when the next storms hit, which contributed to even more destruction.



Brassereidfoss power station: August 9th, 2023 - Overtopping of road bridge, embankment dam and gated dam



Photo 12: Overtopping of road bridge, embankment dam and gated dam at 15:31 (Photo: Police/Source NVE)

DNV was engaged by Hafslund Eco Vannkraft to conduct an investigation of the incident that occurred at Braskereidfoss Power Station on 09/08/2023.



Photo 13: After the failure of the embankment dam at 17:04 (Photo: Police/Source NVE)

Atmospheric river

October 30th, 2024



Den atmosfæriske elven som treffer Norge på torsdag, inneholder vann som kommer langt sørfra. Kartet viser transport av vanndamp i atmosfæren, med sterk transport i mørkeblått og fiolett. III.: Clemens Spensberger

Atmospheric river – end of October 2024

- Are these rainfall amounts impacting you?
- Is there an upper threshold for your operations?



Her etterlot "Jakob" seg mest nedbør Foto: Meteorologisk institutt. Skjermdump frå X.

Still, it came as a surprise.



Future atmospheric rivers can ...

 contain more water vapour -> more intense precipitation

• be wider -> impact a larger region



Composite AR IVT Histogram

Historical (N= 177, 543, 059 RCP8.5 (N= 267, 866, 762)

Espinoza, V., Waliser, D. E., Guan, B., Lavers, D. A., & Ralph, F. M. (2018). Global analysis of climate change projection effects on atmospheric rivers. *Geophysical Research Letters*, *45*(9), 4299-4308. <u>https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2017GL076968</u>

black and grey swan events

Black swan is an outlier causing an extreme impact which lies outside the realm of regular expectations, because nothing in the past can convincingly point to its possibility (Taleb, 2007).

Grey swan is an event that is known and possible to happen, but which is assumed to be unlikely to occur.

There is more information in the past than events which have occurred. Counterfactual thinking: What if?

weather and climate:

reanalysis data: *What has happened* seasonal forecasts: *What may have happened* climate projections: *What can happen*



energy system models:

TIMES: supply capacities demands transmission capacity ENERGYPLAN: test system feasibility hourly balances calibrated storage use and capacities ...

We need your insight for the analytical work within the project

Questions for the group work with users

From your experience which weather situations was/is most critical for your operation(s), business? Why?

How did/do you handle the situation?

Have you implemented any measure(s) to be prepared for climate hazards?

Does it impact the strategic planning of your organization? If yes, how?

Do you have experiences/observations of near failures?



Thanks for your attention!

How to approach the problem?

METEOROLOGY-CENTRED

- Variable by variable
 - temperature
 - precipitation
 - wind speed
 - ...

IMPACT-CENTRED

- high electricity prices
- failures
- near failures
- ...

Drought – summer 2018



Norge

Sommertørken truer vannstanden i norske vannmagasiner

NTB 10. aug. 2018 07:58 - Oppdatert 10. aug. 2018 07:58



Det er lite vann i Loeselva som går mellom Hokksund og Steinberg i Buskerud etter sommerens mangel på nedbør, i likhet med mange småelver på Østlandet. Foto: Ter Bendiksby / NTB scanpix Foto: NTB scanpix

Etter årets voldsomme sommertørke må det regne mer i høst enn på 100 år for å nå vanlig fyllingsnivå i norske vannmagasiner.

The probability for summer droughts has increased.

- What are recent trends of extreme temperatures?
 - We find non-stationarity and positive trends in annual maximum heatwave intensity (TX3d)
- Has the risk for a 100-year heatwave event increased in **Northern Europe?**
 - Yes, almost everywhere.
 - A heatwave event associated with a 100-year return period in 1981 is now estimated to happen once in 20–40 years.
 - The risk for clearly outstanding heatwaves is highest in central Scandinavia.



Berghald et al., 2024, https://iopscience.iop.org/article/10.1088/1748-9326/ad2893/meta

°C/decade) 0 - 0.05

0.05 - 0.1

Annual mean temperature, Norway

Observed change of annual mean temperature for Norway since year 1900, relative to the 1901-2000 mean. The trend lines (grey colour) show the linear trends for the last 100 and 50 years. The string

(X/Y °C/decade)

gives the associated 100 year and 50 year linear slopes in degrees Centigrade per decade.

Mean = ...

gives the mean temperature for the period 1901-2000 (the zero-line in the figure). Last data point is given in the lower right corner of the figure.



Data from Frost of the Norwegian Meteorological Instutute.

Note: Errors may occur since all figures are automatically updated with only sporadic checking. Return to *Temperature* overview. Return to top of page.





Atmospheric river



Om morgenen 26. november 1940 målte værobservatøren i Indre Matre i Kvinnherad 229,6 millimeter nedbør i en regnmåler som var rent over. Dette er den høyeste døgnnedbøren som er registrert i Norge. Kartet viser vanndamptransport i atmosfæren dette døgnet. Mellom lavtrykk over Nord-Atlanteren og Norskehavet og et høytrykk over Mellom-Europa, transporterte sterk vind vanndamp i et konsentrert belte, slik vi forbinder med atmosfæriske elver. Værdata: 20th Century Reanalysis. III.: Ellen Viste