

Black-outs are not an option

An assessment of renewable energy extremes

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10-04-2018



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Introduction

Share of *variable* renewable energy sources will likely increase

Modern society runs on electricity;

) Demand has to be met

Introduction

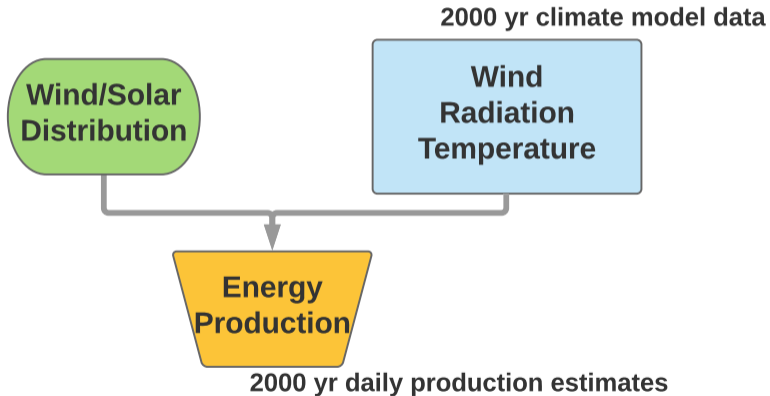
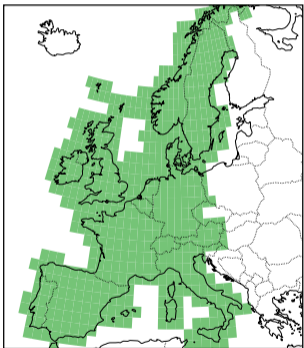
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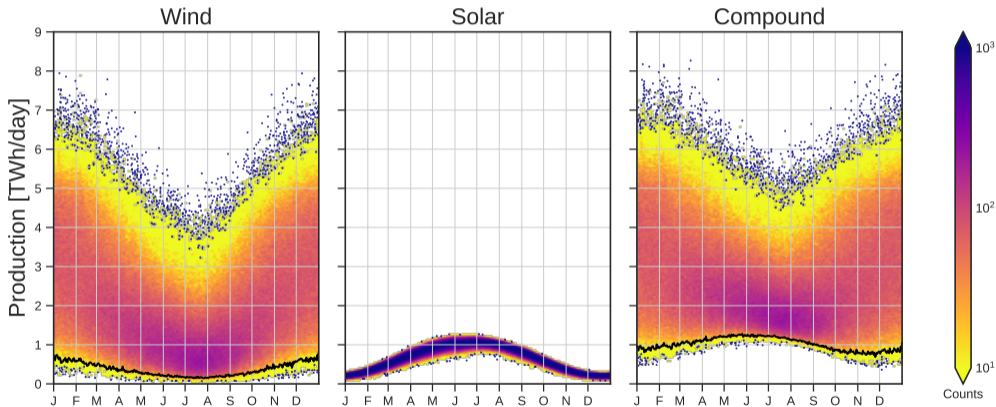
) Demand has to be met

- Properties of production
- Defining demand
- Scale of shortage

Impact model

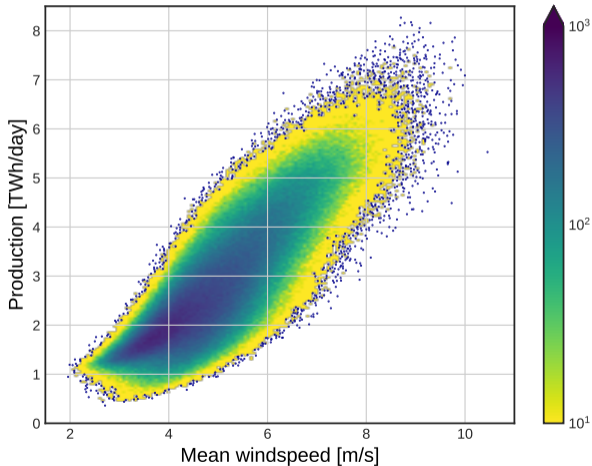


Compound energy production



Wind vs Production

1 day mean



Low production extremes



Lowest wind extremes

Composite weather map for 1 in 10 yr extreme

200 lowest production days (from 365 2000 days)

High pressure system in central Europe
Cold-air from the east

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200 lowest production days (from 365 2000 days)

High pressure system in central Europe

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+

Look at electricity demand

Impact model: historic demand

Winter Heating

Summer cooling

Lowest demand @ 15.4 C

Impact model: demand extension

Compound energy shortage

Note the different Y-axis

Wind vs shortage

1 day mean

1 day mean

Stronger non-linear relationship with demand included

Wind vs energy shortage: longer timescale

1 day mean

14 day mean

Amplified non-linear relationship on longer timescales

Concluding remarks

Properties of Production

-) Compound shifts season of lowest extremes

Defining demand

-) Temperature as an indicator, non-linear relation

Scale of shortage

-) Strong non-linearity, low wind speed $\hat{=}$ high shortage

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Scale of shortage

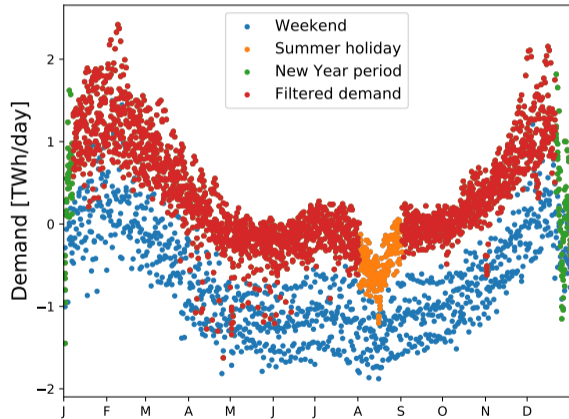
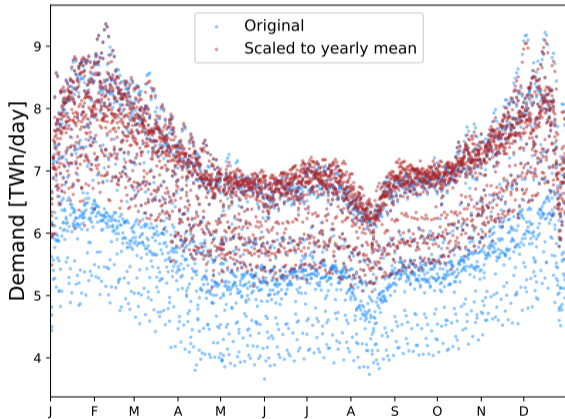
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... Looking for a PhD...

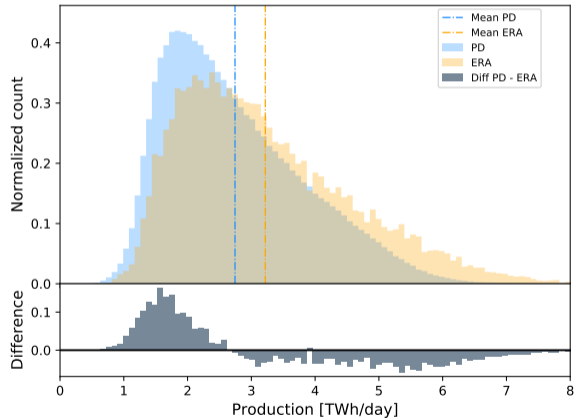
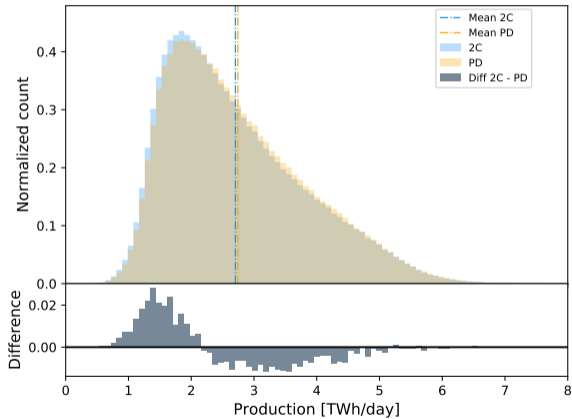
Impact model: references

- 2000 yr EC-Earth climate data, K. van der Wiel
- Realistic capacity EU13+2 by B. van Zuilen & M. van den Broek (in progress)
- ENSTO-E demand data (jan 2006 - dec 2015)
- NASA SEDAC population data (reference year 2015)
- Scaling and powercurves as by S. Jerez et al. (2015)
- From temperature/population to demand, J. Moral-Carcedo, J. Vicens-Otero 2005

Impact model: demand filter



Impact of climate change



Bias with respect to ERA-interim

