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# How much extreme weather events have affected European power generation in the past three decades?

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ABSTRACT

Extreme weather events (EWE) can affect energy supply, particularly when energy systems are significantly reliant on renewable energy sources, highly vulnerable to climate and weather conditions. We combine observational energy data from EUROSTAT with records of EWE, between 1990 and 2019, to evaluate European power plants capacity factors (CF) responses to those events. Using a statistical compositing analysis, we show that years with floods and storms increased annual European hydropower CF by 7 and 5.8%, respectively, compared to non-EWE years, while CF of fossil power plants decreased (−2.8%). Similar behaviours are found for Central and Mediterranean countries. From 1993 to 2004 to 2005–2016 European hydropower tripled during floods and quintupled during storms suggesting that the events are becoming more severe or there is more efficient water use. On the contrary, from 1993 to 2016, in every year with droughts/heatwaves the European hydropower decreased (−6.5%), with a subsequent increase of fossil CF (2.3%). Such behaviour is also observed across Central and Eastern Europe. Cold waves negatively affected solar photovoltaic output at the European level and Central Europe (−5%). Vulnerability of wind power plants to floods is increasing: from 1993 to 2004 to 2005–2016 there is 3-fold decrease in the European wind CF; from one flood year to the following, wind CF decreases in Central (−1.9%$yr^{-1}$) and Eastern Europe (−3.7%$yr^{-1}$). During droughts/heatwaves, wind CF increases in Central Europe (2%$yr^{-1}$), but decreases in Mediterranean (−3%$yr^{-1}$). Shifting to renewable energy sources is key to decarbonization. It's crucial understanding the historical impacts of EWE in the power system towards its resilience and stability.

## 1. Introduction

Extreme weather events (EWE), such as heatwaves, extreme rainfall, or droughts, have potential to interrupt the normal function of the energy system [1,2]. These events can, for instance, interrupt the energy generation or its transmission, interfere with fuel production and distribution, and/or cause fuel and electricity shortages, potentially leading to price spikes [3] (see Fig. 1). As a central example, in July 2021, a forest fire associated to a heatwave in France and Iberian Peninsula led to a power blackout in Portugal and Spain that affected several hundreds of thousands of people [4]. In 2013 strong winds and flooding resulted in power interruptions affecting around 750 000 customers in the United Kingdom and Ireland [5]. EWE are expected to increase in frequency and severity under unabated climate change [6], thus potentially exacerbating the vulnerabilities of the power system and affecting supply reliability [1]. This is relevant specially when power systems are progressively relying on higher shares of renewable energy sources in their supply mix, along with an intensification of electrification of energy uses, namely in heating and transportation.

Particularly, the power capacity of renewables, as wind, hydro, solar photovoltaic (PV), among others, is highly dependent on weather conditions. In 2019, across the European Union (EU), UK and Norway, renewable energy represented nearly 33% of the total European electricity production [7]. This number increased by 12% since 2010 and is planned to increase even more in the EU as a key strategy of the REPowerEU Plan. It has the goal to decrease the external energy dependency, while also decarbonizing and reducing climate change [8–10], [7]. The transition to renewable electricity is at the heart of this

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