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California drought increases CO_2 footprint of energy

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ABSTRACT

This paper discusses the CO_2 footprint of California's drought during 2012–2014. We show that California drought significantly increased CO_2 emissions of the energy sector by around 22 million metric tons, indicating 33% increase in the annual CO_2 emissions compared to pre-drought conditions. We argue that CO_2 emission of climate extremes deserve more attention, because their cumulative impacts on CO_2 emissions are staggering. Most countries, including the United States, do not have a comprehensive a nationwide energy-water plan to minimize their CO_2 emissions. We argue that developing a national water-energy plan under a changing climate should be prioritized in the coming years.

1. Introduction

California has been experiencing an unprecedented multi-year (2012-present) drought characterized by low precipitation and extreme temperatures (Shukla et al., 2015), leading to significant socio-economic and environmental impacts (Diffenbaugh et al., 2015,). The drought's continued effects on the energy sector are also unprecedented. Hydropower production was reduced from 21.2% (42,732 GWh) of the state's total energy in 2011 to 8.3% (16,476 GWh) in 2014 (Fig. 1), primarily due to sustained below average precipitation and snowpack. Consequently, natural gas use for electric power production has increased to compensate, causing a significant boost in CO_2 emissions. The additional CO_2 emissions from electric generation in 2012–2014 are estimated to be nearly 22 million metric tons compared to a similar period (2009–2011) prior to the ongoing drought (i.e., equivalent to 0.57 metric tons of CO_2 per capita). This constitutes a 33% increase in the annual CO_2 emissions during 2012–2014 compared to 2011, equivalent to the annual energy use of 1 million homes or annual emissions of 1.5 million passenger vehicles (EPA, 2016) – see Supplementary materials.

The carbon footprint of the California drought has been significant, but could have been worse. Thanks to the state's aggressive plan to increase its renewable energy (CEC, 2015), solar and wind power generation has seen an abrupt increase of 270% since 2011 (Fig. 1), in comparison to the approximately 7.6% increase per year in share of these energies in previous decades. Without this substantial increase in renewable energy supply, the CO_2 footprint of the current drought would have been much higher (S1 in Fig. 1). Assuming 2011 levels of renewable energy, the CO_2 emission during the current drought would have increased by 44% compared to 2011 (35.9 million metric tons over 2012–2014). The CO_2 footprint of California drought appears to be small relative to the overall global emission. However, droughts (and other extreme events) happen all the time and around the world. The cumulative impact of the tyranny of climate extremes adds up. This simple example highlights how policy changes toward having more renewable energy can offset CO_2 emissions caused by abnormal weather and climate conditions.

The role of anthropogenic CO_2 emissions in changing our climate is well understood (Solomon et al., 2009). A major question is how climate extremes (including short-term shocks) can exacerbate CO_2 emissions, especially since extreme climate events are expected to increase in the future (IPCC, 2013). In California, for example, studies show that climate change and variability could lead to more extreme droughts in the future (Cayan et al., 2010; Cook et al., 2015; Seager et al., 2007). Rising temperatures might

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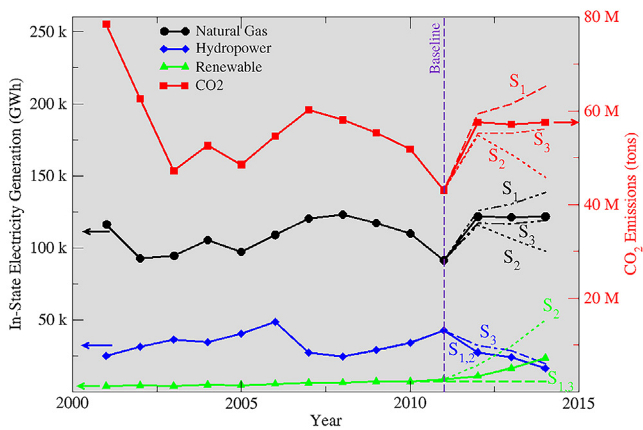

Fig. 1. Time series of natural gas used for power generation (black), hydropower energy production (blue), renewable energy (Solar + Wind) (green), and CO_2 emissions (red). Solid lines represent actual data from 2000 to 2014. Dotted lines indicate four scenarios: renewable energy had not increased substantially post 2011 (S1); a future drought but with 2.5 times the renewable energy compared to 2014 (S2); 25% reduction in urban water use (S3). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

reduce snowpack (or at least cause faster snowmelt) and hence, change the magnitude and timing of water supplies (Bales et al., 2006; Barnett Tim et al., 2008; Vicuna & Dracup, 2007). Climate change is expected to reduce hydropower production and exacerbate the current mismatch between hydroelectricity supply and demand (Madani, Guégan, & Uvo, 2014; Guégan, Uvo, & Madani, 2012). While there are uncertainties in future climate and how it will change, one thing is certain: population and industries will grow and there will be more competition over water. This leads to more intense *Anthropogenic drought* (AghaKouchak, Feldman, Hoerling, Huxman, & Lund, 2015), meaning water stress caused or intensified by human activities. All these trends emphasize the need for more aggressive plans toward more renewable energy sources with the careful consideration of the possible impacts of such plans on other natural and economic resources (Hadian & Madani, 2015).

Imagine a future drought with a similar duration and impact, but 2.5 times the renewable energy compared to 2014. Our analysis shows that with 2.5 times more solar photovoltaic, solar thermal and wind renewables generating at similar to current levels, an event like the 2012–2014 California drought would not lead to an increase in CO_2 emissions compared to 2011, when emissions were low owing to high contribution of hydropower to the total energy production (Supplementary 2 in Fig. 1). By 2015, nearly 23% of California energy portfolio consists of non-hydro renewable sources, including nuclear and bio-fuels. The state of California is planning to increase renewable energy to 25% by the end of 2016 and to 50% by 2030 (CEC, 2015). These numbers are promising and represent a visionary statewide effort to mitigate CO_2 emissions.

2. Discussion

Water conservation and reducing human water demand can also provide more resources for hydropower generation and hence, reducing CO_2 emissions. However, we argue that domestic water conservation does not necessarily make a significant impact. In response to the California drought, Governor Brown issued an executive order for a mandatory reduction in urban water use by 25%. Saving water during a drought does not necessarily provide additional resources for hydropower generation because there are multiple sectors that compete for limited resources (Supplementary 3 in Fig. 1). Assuming all domestic savings contribute to hydropower production, it would only bring hydro-generation back up by 9.8% of total (from 8.3% total power share). Such increase would reduce the drought's CO_2 footprint by 5.7 million metric tons over the course of 2012–2014. Furthermore, in California there is a major competition between urban, ecological, and industrial water use which limits the impacts of urban water conservation in hydropower production. Water conservation is important and should be considered seriously, but alone it does not compensate for the expected increase in CO_2 emission during droughts. This example highlights how an extreme event can exacerbates CO_2 emissions. Droughts happen around the world and their cumulative impacts on CO_2 emissions are staggering. Water and energy are closely related and the two sectors can be managed to alleviate droughts without exacerbating CO_2 emissions (Tarroja et al., 2014). In many part of the world such as California, food production is also a major component of both the water and energy markets. Yet, most countries, including the United States, do not have a comprehensive nationwide energy-water plan to minimize their CO_2 emissions. Developing such a plan at the nexus between water, energy (and food production where relevant) and under a changing climate should be prioritized in the coming years.

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Annual In-State Electric Generation by Type and CO2 emission from electricity. Data available from: http://energyalmanac.ca.gov/electricity/electric_generation_capacity.html. This study was partially supported by the National Science Foundation Award No. 1639318.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.scs.2016.09.004.

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