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Climate risk management for the U.S. cellulosic biofuels supply chain

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ABSTRACT

As U.S. energy policy turns to bioenergy, and second-generation biofuels in particular, to foster energy security and environmental benefits, consideration should be given to the implications of climate risk for the incipient bioenergy industry. As a case-in-point, we review evidence from the 2012 U.S. drought, underscoring the risk of extreme weather events to the agricultural sector in general, and the bioenergy supply chain in particular, including reductions in feedstock production and higher prices for agricultural commodities and biofuels. We also use a risk management framework developed by the Intergovernmental Panel on Climate Change to review current understanding regarding climate-related hazards, exposure, and vulnerability of the bioenergy supply chain with a particular emphasis on the growing importance of lignocellulosic feedstocks to future bioenergy development. A number of climate-related hazards are projected to become more severe in future decades, and future growth of bioenergy feedstocks is likely to occur disproportionately in regions preferentially exposed to such hazards. However, strategies and opportunities are available across the supply chain to enhance coping and adaptive capacity in response to this risk. In particular, the implications of climate change will be influenced by the expansion of cellulosic feedstocks, particularly perennial grasses and woody biomass. In addition, advancements in feedstock development, logistics, and extension provide opportunities to support the sustainable development of a robust U.S. bioenergy industry as part of a holistic energy and environmental policy. However, given the nascent state of the cellulosic biofuels industry, careful attention should be given to managing climate risk over both short- and long-time scales.

Introduction

The development and use of biofuels as an energy source has increased rapidly in recent years, both in the United States and internationally. Estimates from the energy industry indicate that global use of biofuels increased by a factor of five from

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2001 to 2011 (BP, 2012). Over that same time period, the United States emerged as the single largest national producer of biofuels, accounting for 48% of global production. The growth in biofuels has been driven by two energy-related policy challenges. First, biofuel development has been pursued as means of reducing environmental externalities of traditional fossil fuels. Ethanol was adopted as a fuel additive under the U.S. Clean Air Act Amendments (U.S. Environmental Protection Agency, 2012; USEPA, 2012) and the Alternative Motor Vehicle Fuels Act (USGPO, 1988) as a means of reducing particulate air pollution from transportation. Increasing awareness of climate change as another externality of energy use has provided additional incentives to the use of biofuels in order to offset carbon emissions from traditional fossil fuels. Second, and more recently, a growing national emphasis on energy security has been a key driving force for domestic biofuel production. While almost all the 57 billion liters of U.S. ethanol production in 2012 was derived from corn, policies are designed to foster commercialization of biofuels from non-food crops, specifically lignocellulosic biomass. For example, the Energy Policy Act of 2005 (USGPO, 2005) and the Energy Independence and Security Act (EISA) of 2007 (USGPO, 2007) substantially increased the targets for ethanol production, setting a production goal of 136 billion liters of cellulosic biofuels by 2022 (U.S. Environmental Protection Agency, 2005, 2007).

While bioenergy, including biofuels and biopower, has received significant attention in the literature as a technology for offsetting future greenhouse gas emissions from energy (Adler et al., 2007; Campbell et al., 2008; Field et al., 2008; Schneider and McCarl, 2003), the potential vulnerability of bioenergy production to extreme weather events, climate variability, climate change, and overall climate risk[1] has received comparatively little (de Lucena et al., 2009; Dominguez-Faus et al., 2013; Haberl et al., 2011; Poudel et al., 2011; Schröter et al., 2005; Stone et al., 2010; Tuck et al., 2006; Wilbanks et al., 2012). Recent assessments of the implications of climate change for U.S. energy systems, for example, acknowledge the potential climate sensitivity of bioenergy (CCSP, 2007; Wilbanks et al., 2012), yet contain little discussion of the timing and magnitude of future impacts for different bioenergy resources. As with agricultural and forestry production, bioenergy is highly exposed and sensitive to weather and climate (Wilbanks et al., 2012), and thus may be more vulnerable than other energy sources. For example, Eaves and Eaves (2007) found that the price volatility of grain ethanol is higher than that of gasoline imports due to the impacts of weather. Given predictions that extreme weather events will increase in frequency, duration, and/or intensity (IPCC, 2012), climate risk to biofuels derived from agricultural and forest enterprises would also be expected to increase. The current policy emphasis on cellulosic bioenergy production, as well as the important role of bioenergy in enhancing energy security and reducing climate risk, suggests greater attention to the implications of climate risk for the industry is warranted. As a case-in-point, the U.S. drought experienced during 2012, and its impacts on the agricultural sector, represents a 'teachable moment' for the biofuels industry. As an estimated 1 in 30 years event, it was the first significant, national-scale drought event to coincide with the emergence of the U.S. bioenergy industry. The consequences revealed potential vulnerabilities of the bioenergy supply chain, potential trade-offs among different technologies and feedstocks, as well as opportunities for future risk management. With projected demand of approximately 225 million dry Mg of biomass needed by 2022 to meet EISA targets (Langholtz et al., 2012) and the likely continued expansion of cellulosic bioenergy in future decades, robust climate risk management in the bioenergy industry will be an important component of its evolution and its contributions to meeting U.S. energy security and environmental goals.

Here, we review climate risk to the U.S. bioenergy industry, with a particular emphasis on cellulosic biofuels, which are currently an arena of intensive research and development. We frame our review around a risk-management framework to identify direct and indirect climate hazards, assess exposure, and explore key vulnerabilities, with an emphasis on learning from recent experience with extreme weather events such as the 2012 drought. We also identify risk management strategies for the bioenergy supply chain that may be starting points for adaptation efforts as well as key knowledge gaps that must be addressed through future research and development efforts toward a climate-resilient cellulosic bioenergy supply chain.

Framing climate risk to the bioenergy supply chain

The bioenergy supply chain is comprised of a broad range of assets and infrastructure, both public and private, which have differential vulnerabilities to climate risk (Fig. 1). While much of the focus of biofuel analysis targets the land used to produce biofuels, the industry is dependent upon a more elaborate supply chain that is in some ways analogous to that of other forms of energy (Parish et al., 2013). The foundation for the bioenergy supply chain is the production of bioenergy feedstocks on farms, forestlands, or marginal lands. For cellulosic-based fuels, feedstocks could include crop residues such as corn stover (the most abundant U.S. cellulosic feedstock at present) (Kadam and McMillan, 2003), direct production of energy crops including annual (e.g., sorghum) or perennial (e.g. switchgrass and Miscanthus) herbaceous crop, as well as woody biomass crops (McKendry, 2002). Once harvested, these feedstocks are stored onsite or transported to biorefineries or long-term storage facilities. Biorefineries may store feedstocks for short periods of time and facilitate additional preprocessing before biomass enters the biochemical or thermochemical refining process. Depending on the refinery, the products of refining include liquid fuels such as ethanol as well as syngas, which can be converted to a range of products.

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[1] We use the term "extreme weather event" to indicate a singular occurrence such as a hurricane or storm, "climate variability" to specify variation from expected climate averages, and "climate change" in the conventional sense indicating long-term (multi-decade) trends. In this paper we use the term "climate risk" to mean risk associated with extreme weather events, climate variability, and/or climate change, and we use the specific terms where the distinctions are relevant.