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An examination of electricity generation by utility organizations in the Southeast United States

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ABSTRACT

This study examined the impact of climatic variability on electricity generation in the Southeast United States. The relationship cooling degree days (CDD) and heating degree days (HDD) shared with electricity generation by fuel source was explored. Using seasonal autoregressive integrated weighted average (ARIMA) and seasonal simple exponentially smoothed models, retrospective time series analysis was run. The hypothesized relationship between climatic variability and total electricity generation was supported, where an ARIMA model including CDDs as a predictor explained 57.6% of the variability. The hypothesis that climatic variability would be more predictive of fossil fuel electricity generation than electricity produced by clean energy sources was partially supported. The ARIMA model for natural gas indicated that CDDS were the only predictor for the fossil fuel source, and that 79.4% of the variability was explained. Climatic variability was not predictive of electricity generation from coal or petroleum, where simple seasonal exponentially smoothed models emerged. However, HDDs were a positive predictor of hydroelectric electricity production, where 48.9% of the variability in the clean energy source was explained by an ARIMA model. Implications related to base load electricity from fossil fuels, and future electricity generation projections relative to extremes and climate change are discussed.

1. Electricity consumption and generation

The trends in carbon emissions, electricity consumption, and fuel source mix for electricity generation remain a major concern globally. This is particularly true in the United States (US), where on a per capita basis the US is approximately four times as consumptive as China, the largest electricity consumer in the world[37]. It is widely noted that increased climatic variability and global mean temperature change is anthropogenic forced [20]. During the recent United Nations Framework Convention on Climate Change, the US along with the overwhelming majority of countries around the world adopted the Paris Agreement, with the shared goal of limiting global mean temperature increase to 1.5 °C above pre-industrial levels [36]. This agreement signals a global commitment to reduce reliance on fossil fuels.

The focus on energy generation and fossil fuels is magnified considering that 90 entities, primarily energy production organizations, have emitted over 60% of the global carbon since the 1850's [16]. As shown in Fig. 1, between 2000 and 2013 the focal Southeastern US state for this study saw a steady increase of electricity generation from fossil fuels, highlighting the urgent need to explore the role of efficiency, policy, climatic variability, and stakeholder engagement to mitigate the negative consequences related to this electricity consumption and generation. The goal of the current study is to gain a clearer understanding of the impact that short-and long-term climatic variability have on electricity generation in the Southeast US. Accordingly, the next section will review the relevant literature and provide hypotheses. A methods section will then be presented, followed by results and discussion sections.

1.1. Literature review

Utility organizations in the Southeast remain reliant on fossil fuels as the primary source for electricity generation [38]. Furthermore, states in this region rely more heavily on electric cooling and heating equipment, contributing to greater electricity consumption per capita [37,41]. Throughout the US, electricity

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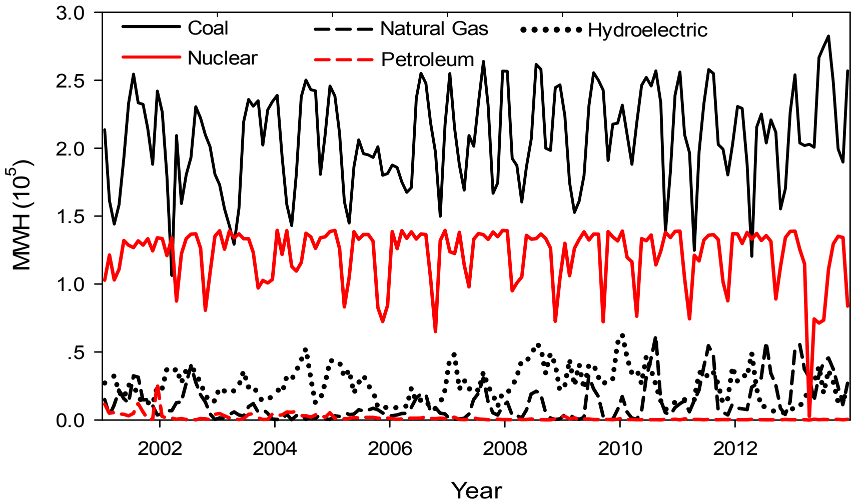

Fig. 1. Monthly MWH electricity generation by fuel source between 2000 and 2013.

generation and consumption are closely linked [7]. Trends such as increased economic activity, population growth, concerns over a reliable source of electricity, and new uses for electricity are several forces driving electricity consumption and continued use of fossil fuels for generation [22,29,30,32,33].

In the focal Southeastern region, a recent study demonstrated that increased temperatures shared the most salient relationship with increased electricity consumption [8]. Increased temperatures are projected to increase demand for electricity in the future [23]. The impacts of temperature and drought are prohibitive to utility organizations as well. For instance [2], estimate that electricity production in the Western US could diminish by over 8% as a result of drought. Between 2031 and 2060, van Vliet et al. [45] project diminished capacity in US power plants between 6.3% and 19% during summer months related to the prevalence of thermoelectric generation in the US. Globally, van Vliet et al. [44] project that power from thermoelectric plants could reduce by over 80% in extreme future conditions. Drought, temperature, and costly extreme weather events are all projected to increase in the Southeast US (Ingram et al., 2013; Preston), making the regions' electricity generation capacity particularly vulnerable.

Outside intervening factors, such as more stringent policies related to efficiency programs or emissions reduction, for-profit organizations such as investor-owned utility organizations will pursue profit-seeking behaviors [34,47]. There has been public scrutiny over efficiency efforts and use of clean energy by utility organizations [9]. However, information asymmetry, or incomplete/withheld information, by investor-owned organizations make it difficult for the public to understand the implications of emissions from fossil fuels and for policy makers to enact quantify the true impact of electricity generation [14]. The lack of focus changing climatic conditions and the increase in extreme weather events further complicate the ability of utility organizations to adequately plan for future electricity demand [2,7].

Policies related to fuel source for electricity generation are particularly relevant in the Southeast US. Biesecker [3] noted that fossil fuel reliant states teamed together to challenge the United States Environmental Protection (EPA) Agency's Clean Power Act, including Arkansas, Alabama, Georgia, Kentucky, Louisiana, Oklahoma, and Texas. In Michigan et al. v. EPA et al. [24]; the act was overturned by majority Supreme Court decision because the costs of implementation were not fully considered for power plants to make changes to achieve the aggressive carbon reduction goals. The EPA evaluation of health benefits have not been fully realized in the past [13], making it more difficult to effectively enact policy. Graves [14] reiterated the shortcomings with realizing the benefits from environmental policies, noting that oftentimes the “big picture” implications, such as the global implications addressed in the Paris Agreement [36] or anthropogenic forced climate change [20], are overlooked in quantifying benefits resulting in the rejection of policies in the US.

Investor-owned utility organizations have turned to energy efficiency programs as a potential market-based solution to reduce consumption and related emissions. In fact, over $7 billion were spent on efficiency programs in 2013, the vast majority of which targeted reduction in electricity consumption [18]. However, a meta-analysis from 1975 until 2012 found that outside rich feedback mechanisms, incentives spent on efficiency improvements resulted in an increase in electricity consumption (Delmas et al., 2013). This has been referred to as the rebound effect, where efficiency improvements are counteracted by outside factors such as adding electrical devices or increased usage behavior [19]. The rebound effect does not always result in counterintuitive results, however, but represents how outside factors prohibit expected efficiencies from being accomplished. The direct rebound effect is often used in electricity studies because the marginal change in demand for usage as operating costs change can be easily quantified (Gillingham et al., 2015). Specific to electricity, a recent study found a residential direct rebound effect between 24% and 37% for households in response to electricity price change [46]. Specific to efficiency upgrades, Davis et al. [10] found that subsidies for efficient air conditioners increased electricity consumption among consumers, while the savings from efficient refrigerators were nominal.

Environmental messages have been used to combat the unintended consequences of diminished electricity savings associated with the rebound effect [1,9]. For instance, Asensio and Delmas [1] found that the topic and frequency of which a message is delivered to residential electricity users influenced persistent electricity savings over time in a longitudinal study. Research has shown that levels of awareness about a pro-conservation behavior impact the manner in which gain- and loss-framed messages influence enactment of behaviors [9,27]. Furthermore, Fielder [12] discussed using messages highlighting desirability and/or feasibility to influence future perceptions and/or behaviors. In terms of policy and efficiency spending, the majority of Southeastern states rank in the