Introduction

The latest International Energy Agency (IEA) *Net-Zero by 2050* report develops a roadmap for the global energy sector to achieve net-zero emissions and offers an in-depth analysis of pathways for meeting emissions targets [1]. In addition to accomplishing climate goals, the report highlights that a wider implication of a net-zero energy system is the potential for greater consequences associated with power interruptions, due to increased electrification present in many net-zero pathways. Because the grid is often vulnerable to the effects of severe weather, there is a clear need to mitigate the consequences of climatological threats to electricity infrastructure.

Historical data from the U.S. National Oceanic and Atmospheric Administration (NOAA) indicate an upward trend in the frequency and impact of high-impact weather disasters [2], [3]. These extreme weather events often cause power outages [4], [5] along and adjacent to their tracks. For example, Hurricanes Michael and Florence both occurred in 2018 and resulted in power outages for an estimated 1.7 million people across six southeastern states. That year, customers in affected states experienced an average of 30 hours of power outages [6]. During the California wildfires in 2019, the utilities issued power outages to nearly 500,000 people [7]. A week-long freeze in Texas in February 2021 affected 4.5 million people at its peak [8].

In addition to costly physical damages from severe weather events, annual power outages induce an average of $25 billion in economic damages due to lost economic activity [9]. These economic consequences reflect the country’s reliance on the power system for many industries and critical services, including clean water, communications, education, healthcare services, national security, and production and extraction of essential fuels. The combination of increases in electrification for net-zero pathways, severe weather events, and dependency on the electric grid further indicate that improving the ability of the electric grid to withstand and recover from major weather events could have significant economic and social benefits.

The concept of withstanding disturbances such as hurricanes or wildfires that would otherwise cause power outages has taken many forms in the literature, namely as resilience. Resilience is recognized as an important initiative on the international scale. For example, resilience is included in the Sustainable Development Goals (SDGs) adopted by members of the United Nations: goal 9 emphasizes building resilient infrastructure and goal 11 strives to make cities resilient [10].

The varying and broad definitions of resilience present a challenge when trying to incorporate resilience decision-making into investment and operational models. Specifically, when attempting to represent resilience in power system tools—such as power system optimization models that could be used for short-term operations and long-term investment planning of renewable systems—the necessary metrics and scenario definitions are unclear [11]–[13]. We investigate the current implementation of resilience considerations and determine the benefits of including them in power system planning models. This paper directs improvements for the incorporation of resilience to minimize the consequences of weather-induced power outages into investment and operational decisions made by power system optimization models [14]. Throughout this review, we explore the power system resilience implications of renewables and how they can meet both the United Nations SDGs and the IEA net-zero initiatives for a resilient and sustainable future.

* Extreme weather events will increase in severity and frequency.
* As a result, the economic consequences of such events, will increase, too.
* There is a need for energy system planning tools capable of considering future climate states, including the anticipated extreme weather events

Literature Review-identify primary gaps

* Long duration outages
* Extreme weather
* Influence policy changes
* Lack of ROBUST decision making

Methodologies (and backing up decisions)

* Data acquisition
* Data manipulation using sophisticated statistical methods coupled with IPCC climate projections
* Robust decision making under deep uncertainty
  + Flow diagram and discuss various steps

Analysis and comparison

* List intended goals of these steps

Appendices

* Mathematical descriptions of PRIM
* LHS
* Statistical methods for projecting climate futures/severe events