Conceptualizing Energy Security and Resilience

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Background:

Energy system resilience is inextricably linked with climate resilience, because the transition to a safe and secure grid powered by renewables is central to both adaptation and mitigation efforts. As geopolitical tensions intensify and as it becomes clear how integral supply chains are to our clean energy future, the term *energy security* has become a central concept, similar to *resilience* in the climate and energy lexicon. This project seeks to understand the role of energy system resilience within energy security. The key research questions are: How are energy system resilience and energy security related? And what is the role of renewables within both security and resilience? A strong conceptual understanding of these terms will set the stage for truly accelerating secure and resilient innovations at scale.

Key Findings:

Energy security and energy system resilience characterize overlapping problem and solution sets. Just as reliability and energy system resilience have different emphases but both contribute to a stable power system, energy system resilience and energy security are complementary concepts with individual areas of focus. Energy security includes some dimensions of resilience but also has distinguishable emphases across the areas of availability, affordability, accessibility, sustainability, and acceptability. An appreciation for the relative areas of focus within energy system resilience and energy security helps us understand how the two concepts can best inform one another to support global adaptation and mitigation efforts while transitioning to a clean energy future.

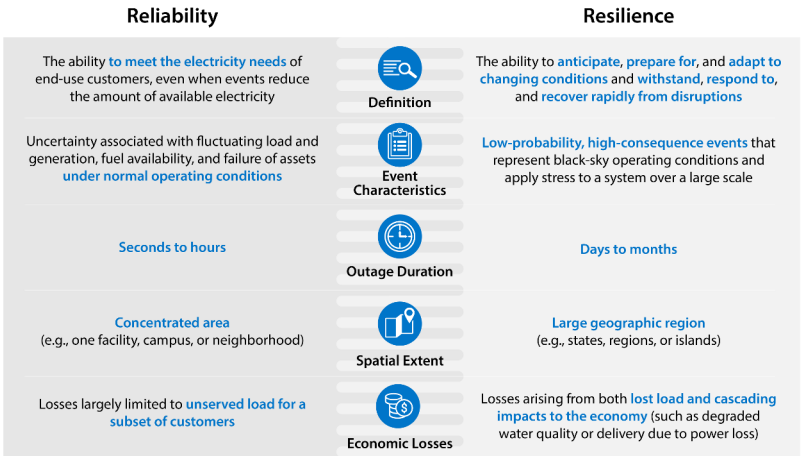
Energy System Resilience

What is resilience?

The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions (Hotchkiss and Dane 2019).

What does resilience emphasize?

- Impacts of low-probability, high-consequence disruptions
- Energy system vulnerability to major disruptions
- Power interruption costs for utilities and customers.



Reliability versus resilience: conceptual expansion
From Leddy et al. (2023)

What is the role of renewables in energy system resilience?

Renewable technologies and distributed generation can contribute to energy system resilience by diversifying and decentralizing energy infrastructure (Sovacool 2016). Specific resilience benefits include the rapid deployment of modular technologies, "islanding" capabilities that allow systems to operate independently from the grid, and greater distribution system flexibility to address all hazards (Cox et al. 2017; Schneider et al. 2021). If adequately coordinated and implemented, the aggregation of various distributed energy components can also support grid services such as frequency response, load shifting, and voltage regulation (Matsuda-Dunn et al. 2023).

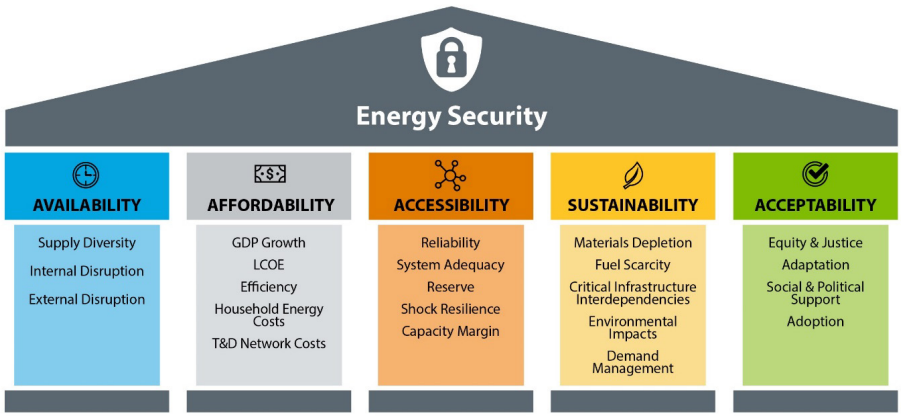
Energy Security

What is energy security?

The uninterrupted availability of energy sources at an affordable price while minimizing negative consequences from energy use, including efficiency, environmental, social, and geopolitical factors (Ang, Choong, and Ng 2015).

What does energy security emphasize?

- Availability, affordability, accessibility, sustainability, and acceptability of energy resources
- Geopolitical impacts on energy access
- Long-term energy system planning at a national scale.



Pillars of energy security
Graphic modified from Cox (2014)

What is the role of renewables in energy security?

The main contribution of renewable energy technologies to energy security is through diversification—renewable technologies can diversify a country's generation mix, helping to decentralize energy supply and reduce energy import dependency (Steinberger-Wilckens et al. 2017). Distributed generation can also provide spatial diversity by spreading out important energy sector assets (Ang, Choong, and Ng 2015). Renewable energy resources further support the sustainability dimension of energy security by helping to meet emissions reduction and climate mitigation goals (Cherp and Jewell 2014). As renewable energy becomes increasingly strategic, new challenges arise—including issues such as intermittency and operating costs, governance and global coherence, and competition for raw materials (Hache 2018).

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