Nuclear Operations and Intermittent Renewables in the United States

Extended abstract

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1 Introduction

In 2023–2024, Southern Nuclear commissioned two nuclear units at the Vogtle power plant in Waynesboro, Georgia.[1] These reactors are the first large increase in the size of the U.S. nuclear fleet in over three decades (Makarin et al., 2024). Although a previous "nuclear renaissance" was aborted in the early 2010s following the Fukushima disaster (Davis, 2012; Joskow and Parsons, 2012), many observers again envision a significant increase in nuclear capacity as a complementary strategy to the massive deployment of wind and solar (Sepulveda et al., 2018). This vision is reinforced by forecasts of rapid load growth driven by the boom of artificial intelligence data centers. For example, Microsoft recently contracted with Constellation to restart Three Miles Island Unit 1. In addition, Amazon, Google and Meta are exploring similar partnerships aimed at expanding the amount of nuclear capacity.

If a "nuclear renaissance 2.0" materializes, nuclear units will operate in a drastically different power system from the one that existed in the 1960s and 1970s. In particular, wind and solar installations now generate very substantial amounts of electricity and, because their output is intermittent, other generation technologies must adjust their production to the resulting large fluctuations in the difference between system demand and intermittent renewables production, what is often termed "residual electricity demand."

In contrast to the widely-held belief that nuclear units are inflexible and, therefore, cannot contribute to managing wind and solar intermittency, empirical evidence from France shows that flexible nuclear operations, called "load-following," is actually possible at a large scale (Astier and Wolak, 2026). However, enabling load-following requires technical and institutional adjustments, induces some costs, and faces stringent operational limits.

This paper will expand the analyses in Astier and Wolak (2026) on nuclear load-following and renewables to the context U.S. power systems.

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[1]https://www.energy.gov/edf/vogtle

2 Load-following in the United States

First, we will retrieve all the Nuclear Regulatory Commission's (NRC) daily Power Reactor Status Reports over 1999–2026 time period. We will use this dataset to document which reactors are observed to load-follow and at which frequency.

Second, we will disentangle the different reasons that explain the low amount of load-following by existing nuclear reactors in the United States. Specifically, we will distinguish between three main factors:

1. **Technical:** the oldest reactor designs cannot load-follow.
2. **Institutional:** some jurisdictions do not allow nuclear operators to load-follow, except at the request of the system operator.
3. **Economical:** when nuclear is (almost) never at the margin on the supply side (which we will assess from ISO/RTO market outcome data), then there is no economic case for nuclear load-following.

For U.S. jurisdictions where some amount of load-following is observed (i.e., where the technical and institutional constraints are not binding), we will explore the extent to which the size of the installed nuclear capacity relative to local residual demand (gross consumption minus renewable output) predicts the observed amount of load-following.

This section will conclude by making the point that, looking forward, all new reactor designs will have load-following abilities (i.e., technical constraints will be lifted). The next sections of the paper will therefore explore in turn (i) the political acceptability (institutional constraints); and (ii) the economics of nuclear load-following.

3 The political acceptability of load-following

The most likely rationale for jurisdictions to ban load-following operations is the fear of nuclear accidents. To assess whether this concern is empirically relevant, we will replicate, for the reactors that have the technical ability to load-follow, the analysis of Astier and Wolak (2026). This study finds that, for the French nuclear fleet, one additional load-following event increases on average the baseline hazard rate of forced outages (more precisely, automatic shutdowns) by one percent. In 2024, the last year of data analyzed by Astier and Wolak (2026), the median number of load-following events per generation unit-year was 25, indicating a substantial increase in the baseline hazard rate of an automatic shutdown in 2024 for many nuclear units.

Similarly, we will estimate from NRC daily data a Cox proportional hazards model where the "terminal event" will be the occurrence of a forced outage (scram), and the main covariate of interest the amount of load-following that was performed since the beginning of a fuel cycle.

This analysis will shed some light on the magnitude of the "political risk" (as proxied by the occurrence of automatic shutdowns of generation units) that jurisdictions may face if they were to lift load-following bans.

4 The economics of load-following

Finally, we investigate the economics of an electricity mix consisting of (load-following) nuclear units, large amounts of wind and solar, and various levels of other thermal technologies (coal and natural gas).

Although the decrease in the capacity factor of nuclear units induced by load-following quantified in Astier and Wolak (2026) is relatively small (less than two percentage points on average), it may not paint the whole picture. In particular, while the fleetwide average capacity factor of U.S. nuclear units exceeds 90%, the same indicator barely reaches 75% in France. Therefore, an important open question is whether this gap reflects a feature of an electricity mix dominated by renewables and nuclear, or rather incentives that exist in the United States, but may not exist in France, such as differences in operational incentives faced by generation unit owners (Davis and Wolfram, 2012).

To shed some light on this question, we will compute the average capacity factor of nuclear units at the balancing-authority-year level (country-year level for France), and assess the relationship between the capacity factor of the nuclear fleet and the "excess nuclear capacity," defined as the average, across all hours of the year, of nuclear capacity in excess of residual demand, normalized by installed nuclear capacity. This analysis will leverage the cross-sectional and temporal variation in the size of nuclear capacity relative to residual demand. For example, MISO have had over 10 GW of nuclear over 1999–2026, but the capacity of wind and solar increased from virtually nothing to 70+GW over the same time period. In contrast, as of today, PJM has over 30 GW of nuclear capacity but less than 10 GW of wind and solar capacity.

5 Conclusion

The (in)ability of nuclear units to respond to wind and solar intermittency is a first-order challenge for a "nuclear renaissance" to take place in a renewable-heavy, low-carbon power system. The intended contribution of this proposed paper is to build on the analysis in Astier and Wolak (2026) to explore this question for the United States, the largest nuclear power market in the world, and compare the results across the two countries.

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