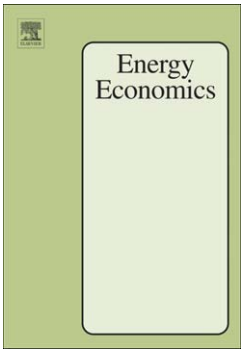

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John E. Bistline

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Economic and Technical Challenges of Flexible Operations under Large-Scale Variable Renewable Deployment

John E. Bistline*

[a]*Electric Power Research Institute, 3420 Hillview Avenue, Palo Alto, CA 94304, USA*

Abstract

Fundamental characteristics of solar and wind power have generated controversy about their economic competitiveness and appropriate techniques for assessing their value. This research presents an approach to quantify the economic value of variable renewable capacity and demonstrates its dependence on renewable deployment levels, regional resource endowments, fleet flexibility, and trade assumptions. It assesses economic and technical impacts of large-scale renewable penetration by linking two models, representing electric-sector investments and detailed operations. Model results for California and Texas suggest operational constraints and costs of dispatchable generators (e.g., minimum load levels, ramping limits, startup costs) can impact renewable integration costs, but the temporal and spatial variability of solar and wind are larger determinants of their value. Restrictions on transmission and regional coordination in capacity planning and dispatch decrease the economic value of variable renewable energy, highlighting the potential roles of market design and trade. Energy storage is shown to be a valuable balancing asset at higher solar and wind penetration levels, but potential revenues diminish with increased storage deployment.

Keywords: Renewable integration, variable renewable energy, power system planning, flexible operations, regional heterogeneity, unit-commitment modeling

*Tel.: +1 650 855 8517.
Email address: jbistline@epri.com (John E. Bistline)