

## **EPRI Energy Systems and Climate Analysis Group Research on the Value, Costs, and Impacts of Renewable Generation**

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This is a summary of all of EPRI's Energy Systems and Climate Analysis (ESCA) Group's research in the renewable generation space, including work in progress. Web links are included where available. Publications marked with an \* are available to the public free of charge, or are published in academic journals. Other publications are available to EPRI member companies that fund certain program(s), as indicated with a number in brackets preceding the publication title and can be purchased by members of the public who may be interested in doing so, subject to EPRI's product distribution requirements. For a full listing of ESCA research that is free to the public, please visit the ESCA public website at <http://eea.epri.com/research.html>. To receive the ESCA group's quarterly newsletter with research updates, please email your request to [eea@epri.com](mailto:eea@epri.com).

### **Economics of High Renewable Generation Penetration**

\* Bistline, J.E. T. and D. T. Young ***Drivers of Economic Wind and Solar Penetration in the United States***. *Environmental Research Letters*, 14, 124001, 2019. <https://doi.org/10.1088/1748-9326/ab4e2d>

\* ***A Primer on Wind and Solar Value Deflation***, EPRI Program 201 Back Pocket Insight, August 2019, <https://eea.epri.com/pdf/Back-Pocket-Insights/EPRI-P201-Decreasing-Returns.pdf>

(201-C) ***Program 201-C Webcast on the Use of LCOE Metrics for Renewable Energy***, July 2019, <https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=41493DA7-98AD-4F90-AF9F-09D38D19ADB8> (webcast recording also available via this link)

(201-C) ***Program 201-C Webcast on the Economics of Storage under Very High Renewable Penetration***, May 2019, <https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=010ED223-F0BA-4260-9708-5590E23FDDF3> (webcast recording also available via this link)

(201-C) ***Program 201-C Webcast on Regional Renewable Penetration***, September 2018, <https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=6C586B9D-12E2-474B-8C04-B86F121F4F38> (webcast recording also available via this link)

(201-C) ***Program 201-C Webcast on Economic Drivers of Wind and Solar***, January 2018, <https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=3EF76A32-FA8A-4664-8553-05C08A602DD2> (webcast recording also available via this link)

(103) ***Program 103 Webcast on the Economics of Storage and Renewable Generation***, May 2017, <https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=933B40CA-3F6E-4ECB-9C75-B1C7AAEC9E8E>

\* ***Decreasing Returns to Renewable Energy***, EPRI Report 3002003946, January 2015, <http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003946>

## Responses to the Academic Literature on '100% Renewables'

(103/178-B) **Challenges to Very High Renewable Penetration: Critique of Jacobson et al. (2015)**. EPRI Report 3002008624, <https://www.epri.com/#/pages/product/000000003002008624/>

\* Bistline, J. E. and G. J. Blanford. **More than One Arrow in the Quiver: Why "100% Renewables" Misses the Mark**. *Proceedings of the National Academy of Sciences*, 113(28): E3988, June 2016, <http://www.pnas.org/content/113/28/E3988>

## Value of Flexible Operations and Ancillary Services under High Renewable Deployment

(178-B) **System Flexibility Investments and Energy Prices in Regional High Renewable Grids: Preliminary Results**, EPRI Report 3002016633, December 2019, <https://membercenter.epri.com/Programs/069228/pages/productabstract.aspx?ProductId=000000003002016633>

\* Bistline, J. E., **Turn Down for What? The Economic Value of Operational Flexibility in Electricity Markets**. *IEEE Transactions on Power Systems*, 34(1):527–534, January 2019, <https://ieeexplore.ieee.org/abstract/document/8412506>

(178-B) **Economic Value of Increased Operational Flexibility for Fossil-Fired Generation Assets**, EPRI Report 3002013735, April 2018, <https://membercenter.epri.com/Programs/069228/pages/productabstract.aspx?ProductId=000000003002013735>

\* Bistline, J. E., **Economic and technical challenges of flexible operations under large-scale variable renewable deployment**. *Energy Economics*, 64:363–372, May 2017, <http://www.sciencedirect.com/science/article/pii/S0140988317301196>

(178-B) **Impact of Variable Renewable Energy on Fossil Fleet Utilization: Insights for the High Plains**, EPRI Report 3002008450, December 2016, <https://membercenter.epri.com/Programs/069228/pages/productabstract.aspx?ProductId=000000003002008450>

(178-B) **The Evolution of Ancillary Services to Facilitate Integration of Variable Renewable and Distributed Energy Resources: A Survey of Some Changes to the Ancillary Services and Ancillary Service Markets**, EPRI Report 3002008987, December 2016, <https://www.epri.com/#/pages/product/000000003002008987/?lang=en>

\* **Technical and Economic Challenges of Flexible Operations: Case Studies of California and Texas**, EPRI Report 3002008242, March 2016, <http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008242>

\* **Program on Technology Innovation: Fossil Fleet Transition with Fuel Changes and Large Scale Variable Renewable Integration**, EPRI Report 3002006517, October 2015, <http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002006517>

## Renewable Mandate Policy Analysis

\* **Impacts of Recent State Renewable Policies in the U.S.**, EPRI Program 201 Back Pocket Insight, December 2019, <https://eea.epri.com/pdf/Back-Pocket-Insights/P201-Back-Pocket-Insight-Recent-State-Policies.pdf>

(201-B) **Program 201-B Webcast on Impacts of Recent and Proposed Renewable Policies**, October 2019,  
<https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=B1ECDAFF-BEE8-4204-A07F-46ED0AE087C7> (webcast recording also available via this link)

(201-B) **Program 201-B Webcast on Analysis of the Smith-Luján Proposed Clean Energy Standard**, June 2019,  
<https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=49F082DC-F775-4908-BFFA-00C8DAAD089D> (webcast recording also available via this link)

\* Bistline, J., Santen, N., and D. Young. **The Economic Geography of Variable Renewable Energy and Impacts of Trade Formulations for Renewable Mandates**, *Renewable and Sustainable Energy Reviews* 106:79-96, May 2019,  
<https://www.sciencedirect.com/science/article/pii/S1364032119301194>

\* **Minnesota High Renewable Standards Insights**, EPRI Program 201 Back Pocket Insight, March 2019,  
[https://eea.epri.com/pdf/Back-Pocket-Insights/MN\\_HRS\\_Back\\_Pocket\\_Insight\\_20190305\\_FINAL.pdf](https://eea.epri.com/pdf/Back-Pocket-Insights/MN_HRS_Back_Pocket_Insight_20190305_FINAL.pdf)

\* **Cost-Effectively Achieving Carbon Goals in Minnesota: Renewable Standards vs. Technology-Neutral Policies — A scenario-based analysis of electric-sector impacts through 2050**. EPRI Report 3002015420, March 2019,  
<https://www.epri.com/#/pages/product/3002015420/>

(201-B) **Program 201-B Webcast on the Economic Geography of Variable Renewable Energy and Impacts of Trade Formulations for Renewable Mandates**, January 2019,  
[https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=4C3CEB49-F3F1-444C-B85B-2D67A57D77D9&eventScope=Cockpit&referer=EVENT\\_LIST](https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=4C3CEB49-F3F1-444C-B85B-2D67A57D77D9&eventScope=Cockpit&referer=EVENT_LIST) (webcast recording also available via this link)

(201-C) **Program 201-C Webcast on California's Rooftop PV Mandate**, November 2018,  
<https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=D52C707B-CDEE-4664-B2E8-815D5D24DA1D> (webcast recording also available via this link)

(201-B) **Program 201-B Webcast on Insights into Clean Energy Standards with Restrictions on Eligible Technologies**, October 2018,  
<https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=577B426F-4774-417D-908E-9495B2339660>

\* **The Costs and Value of Renewable Portfolio Standards**, EPRI Program 201 Back Pocket Insight, July 2018,  
<http://eea.epri.com/pdf/EPRI-P201-Value-and-Costs-of-State-RPS.pdf>

\* Young, D. T. and J. E. Bistline, **The Costs and Value of Renewable Portfolio Standards in Meeting Decarbonization Goals**, *Energy Economics* 73:337-351, June 2018,  
<https://www.sciencedirect.com/science/article/pii/S0140988318301427>

(103) **Program 103 Webcasts on True Costs of Renewable Portfolio Standards**, June 2017 (preliminary)  
<https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=01785E0F-1DA1-49C2-941D-7E78592B9CE6> and November 2017 (final)  
<https://membercenter.epri.com/Programs/109396/pages/eventdetails.aspx?eventID=C2B6173D-2C33-4574-9EC9-F522A48E27BF>

\* **Systems Analysis in Electric Power Sector Modeling: Evaluating Model Complexity for Long-Range Planning**. EPRI Report 3002011365, October 2017, <https://www.epri.com/#/pages/product/3002011365/>

## Representing High Renewable Penetration in Capacity Planning Models

\* ***The Role of Input Assumptions and Model Structures in Projections of Variable Renewable Energy: A Multi-Model Perspective of the U.S. Electricity System***, *Energy Economics* 76:313-324, October 2018, <https://www.sciencedirect.com/science/article/pii/S0140988318304213> Part of the DOE Inter-model Comparison Study on the Representation of Renewables, co-authored by EIA, EPRI, and NREL.

\* Blanford, G. J., J. H. Merrick, J. E. Bistline, and D. T. Young, ***Simulating Annual Variation in Load, Wind, and Solar by Representative Hour Selection***, *The Energy Journal* 39(3):189-212, June 2018, <http://www.iaee.org/energyjournal/article/3083>

\* ***Variable Renewable Energy in Long-Term Planning Models: A Multi-Model Perspective***, NREL Report NREL/TP-6A20-70528, November 2017, <https://www.nrel.gov/docs/fy18osti/70528.pdf> . Part of the DOE Inter-model Comparison Study on the Representation of Renewables, co-authored by EIA, EPA, EPRI, and NREL.

\* ***Simulating Annual Variation in Load, Wind, and Solar by Representative Hour Selection***, EPRI Report 3002008653, June 2016, <http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008653>

## Evaluating the Potential Impact of Changes in Renewable Resources Technology Cost and Performance and Changes in Future Renewables Policies on Future Energy Generation and Capacity Changes

(178-B) ***2019 REGEN Scenarios Analysis: Understanding Key Factors That May Impact the Evolution of Electricity Generation in the United States 2015-2050***, EPRI Report 3002016570, December 2019, <http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002016570> .

(178-B) ***2018 REGEN Scenarios Analysis: Understanding Key Factors That May Impact Future Electricity Generation***, EPRI Report 3002013733, December 2018, <https://www.epri.com/#/pages/product/000000003002013733/?lang=en> .

(178-B) ***2017 REGEN Scenarios Analysis: Understanding Key Factors That May Impact Future Electricity Generation***, EPRI Report 3002011044, December 2017, <https://www.epri.com/#/pages/product/000000003002011044/?lang=en> .

(178-B) ***2016 REGEN Scenarios Analysis: Understanding Key Factors That May Impact Future Electricity Generation***, EPRI Report 3002008451, December 2016, <https://www.epri.com/#/pages/product/000000003002008451/?lang=en> .

(178-B) ***2015 REGEN Scenarios Analysis: Understanding Key Factors That May Impact Future Electricity Generation***, EPRI Report 3002005839, December 2015, <https://www.epri.com/#/pages/product/000000003002005839/?lang=en> .

(178-B) ***2014 REGEN Scenarios Analysis: Understanding Key Factors That May Impact Future Electricity Generation***, EPRI Report 3002004880, December 2014, <https://www.epri.com/#/pages/product/000000003002004880/?lang=en> .

## Renewable Technology Cost and Performance

(178-A) ***Cost of Cycling Phase II: A Technology Assessment Guide Associated Program Study***, EPRI Report 3002016563, August 2019,

<http://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002016563>

(178-A) ***Technical Assessment Guide Web (TAGWeb) Database & Software***, version 3.5, EPRI Software 3002012114, 2018, <https://www.epri.com/#/pages/product/000000003002012114/?lang=en>

(178-B, P174) ***Forecasting Photovoltaics Market Potential: Methods and Approaches***, EPRI Report 3002005775, 2015, <https://www.epri.com/#/pages/product/000000003002015775/?lang=en>

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