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.

ECONOMICS OF HIGH RENEWABLE GENERATION PENETRATION

* ***Impacts of Wind and Solar Costs on Electric Sector Decarbonization***, EPRI Insight, May 2022, https://esca.epri.com/pdf/Back-Pocket-Insights/Renewables_Cost_TwoPager_FINAL.pdf

* Young, D; Bistline, JET; Cole, W; Mai, T. 2021. ***The Outlook for Wind and Solar Deployment: Drivers and Constraints***. Published in EM Magazine, a copyrighted publication of the Air & Waste Management Association, May 2021, https://www.awma.org/content.asp?admin=Y&contentid=707

*Cole, W; Mai, T; Bistline, JET; Young, D. 2021. ***The Current State of Renewable Energy for Electricity***. Published in EM Magazine, a copyrighted publication of the Air & Waste Management Association, May 2021, https://www.awma.org/content.asp?admin=Y&contentid=707

(201-C) ***Program 201-C Webcast on Technological Options and Uncertainties for Very High CO_2 Reductions***, March 2020, https://www.epri.com/events/D8E91360-8B97-4314-82CC-171C1F2CACE4 (webcast recording also available via this link)

* Bistline, J. and G. Blanford ***Value of Technology in the U.S. Electric Power Sector: Impacts of Full Portfolios and Technological Change on the Costs of Meeting Decarbonization Goals***. *Energy Economics* 84:104694, February 2020, https://doi.org/10.1016/j.eneco.2020.104694

* 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

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(201-C) ***Program 201-C Webcast on the Use of LCOE Metrics for Renewable Energy***, July 2019, https://www.epri.com/events/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://www.epri.com/events/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://www.epri.com/events/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://www.epri.com/events/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://www.epri.com/events/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

VALUE OF FLEXIBLE OPERATIONS AND ANCILLARY SERVICES UNDER HIGH RENEWABLE DEPLOYMENT

(178B) ***Webcast: "Enabling Load Flexibility for a High Renewable Future"***, February 2022, https://www.epri.com/research/programs/069228/events/5C89014F-20F5-4A63-99EC-135EF164EB6A (webcast recording also available via the link)

Enabling Load Flexibility for a High Renewable Future: Considerations for Resource Planning, EPRI Report 3002021219, December 2021, https://www.epri.com/research/programs/069228/results/3002021219

(178-B) ***Synchronous Condenser Impact on Stability and Inertial Support on KEPCO's Jeju Island***, EPRI Report 3002025111, June 2022, https://www.epri.com/research/programs/069228/results/3002025111

(178-B) ***Program 178-B Webcast on Enabling Load Flexibility for a High Renewable Future***, June 2021, https://www.epri.com/events/49C71292-573F-4669-9397-986E6E47A1DD (webcast slides also available via the link)

(178-B) ***System Flexibility Investments and Energy Prices in Regional High Renewable Grids: Preliminary Results***, EPRI Report 3002016633, December 2019, https://www.epri.com/research/products/000000003002018501

* 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://www.epri.com/research/products/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://www.epri.com/research/products/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://www.epri.com/events/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://www.epri.com/events/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

* ***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://www.epri.com/events/4C3CEB49-F3F1-444C-B85B-2D67A57D77D9 (webcast recording also available via this link)

(201-C) ***Program 201-C Webcast on California's Rooftop PV Mandate***, November 2018, https://www.epri.com/events/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://www.epri.com/events/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://www.epri.com/events/01785E0F-1DA1-49C2-941D-7E78592B9CE6 and November 2017 (final) https://www.epri.com/events/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

* ***Analysis of Foresight in Long-Term Energy System Models***, EPRI Report 3002021161, December 2021, https://www.epri.com/research/programs/109396/results/3002021161

* Bistline, J.E., G. J. Blanford, T Mai, J Merrick. ***Modeling Variable Renewable Energy and Storage in the Power Sector***. *Energy Policy*. 156:112424, September 2021, https://doi.org/10.1016/j.enpol.2021.112424

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* Bistline, J.E. ***Variability in Deeply Decarbonized Electricity Systems***. *Environmental Science & Technology*. 55:9:5629-5635. April 2021, https://doi.org/10.1021/acs.est.0c06708

ESCA Perspective on Berkeley Report "2035: Plummeting Solar, Wind, and Battery Costs Can Accelerate Our Clean Electricity Future", Program 201 Perspective, June 2020, https://membercenter.epri.com/Programs/109396/Documents/EPRI%20ESCA%20Perspective%20-%202035%20Report.pdf

(201-C) ***Program 201-C Webcast on 2020 Research Summary of Beyond 80% (Temporal Resolution explanation) and 2021 Research Prioritization***, March 2021, https://www.epri.com/events/535AE4B4-7F9D-46F0-8B4C-57F76C683573 (webcast recording also available via this link)

* ***Temperature Impacts on Electricity Demand: US-REGEN Load Projections for Climate Resilience***, EPRI Report 3002020013, February 2021, https://www.epri.com/research/products/000000003002020013

* ***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

* Bistline, J., N. Abhyankar, G. Blanford, L. Clarke, R. Fakhry, H. McJeon, J. Reilly, C. Roney, T. Wilson, M. Yuan, and A. Zhao (2022): ***"Actions for Reducing U.S. Emissions at Least 50% by 2030"*** (*Science*), May 2022, https://www.science.org/doi/pdf/10.1126/science.abn0661

* ***Actions for Reducing U.S. Emissions at Least 50% by 2030***, EPRI Insight, May 2022, https://publicdownload.epri.com/PublicAttachmentDownload.svc/AttachmentId=78689

* ***Understanding Generation and Storage Technology Supply Chain Risks and Needs to Support Electric Utility Sector Decarbonization***, EPRI Report 3002023228, May 2022, https://www.epri.com/research/products/000000003002023228

* ***Electric Utility Workforce Development and Decarbonization***, EPRI Report 3002023229, March 2022, https://www.epri.com/research/products/000000003002023229

(178B) ***Webcast: 2022 REGEN Scenarios Analysis – Project Kickoff***, March 2022, https://www.epri.com/research/programs/069228/events/C9611155-92A8-47AB-A9AD-3FCF526C2F11 (webcast recording also available via the link)

* ***Strategies and Actions for Achieving a 50% Reduction in U.S. Greenhouse Gas Emissions by 2030***, EPRI Report 3002023165, November 2021, https://www.epri.com/research/products/3002023165

2021 REGEN Scenarios Analysis Project: Final Results, EPRI Report 3002022003, December 2021, https://www.epri.com/research/programs/069228/results/3002022003

Understanding Interactions Between Electric-sector and Economy-wide CO_2 Policies, EPRI Report 3002021397, December 2021, https://www.epri.com/research/programs/109396/results/3002021397

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* ***Canadian National Electrification Assessment: Electrification Opportunities for Canada's Energy Future***, EPRI Report 3002021160, September 2021, https://www.epri.com/research/programs/109396/results/3002021160

(201-C, 178-A) ***Program 201-C and 178-A Webcast on Renewable Costs and Planning Impacts***, August 2021, https://www.epri.com/research/programs/109396/events/E53E23B2-C0A4-4D88-84D3-F617F9BB026F (webcast recording also available via this link)

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(201-D) ***Program 201-D Webcast on Strategies for Achieving 50% Emissions Reductions in the U.S. by 2030***, May 2021, https://www.epri.com/events/CEA141BB-8A62-48D2-AE64-7EEC7A78E15B (webcast recording also available via this link)

Long Term Planning Considerations for Hybrid Renewable- Plus- Storage Resources, EPRI Report 3002019611, April 2021, https://www.epri.com/research/programs/109396/results/3002019611

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2020 REGEN Scenarios Analysis: Understanding Key Factors that May Impact Future Electricity Generation, EPRI Report 3002018503, December 2020, https://www.epri.com/research/programs/069228/results/3002018503

(201-C) ***Program 201-C Webcast on Technology Investment and Cost Impacts of 90% Clean Electricity by 2035***, December 2020, https://www.epri.com/events/66DCFB3E-24D2-4068-84F6-D0178A4EF77C (webcast recording also available via the link)

* Bistline, J; Brown, M.; Siddiqui, S.; Vaillancourt, K. ***Electric Sector Impacts of Renewable Policy Coordination: A Multi-Model Study of the North American Energy System***. *Energy Policy*, 145: 111707, October 2020, https://doi.org/10.1016/j.enpol.2020.111707

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(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, https://www.epri.com/research/products/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/000000003002004851/?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

RESPONSES TO THE ACADEMIC LITERATURE ON '100% RENEWABLES'

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About EPRI

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