Economic drivers of wind and solar penetration in the US

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Abstract
Much has been made of the potential for wind and solar generation to supply cheap, low-emissions electricity, but considerable disagreement exists as to which combinations of many potential drivers will enable deep penetration of these technologies. Most existing analyses consider limited factors in isolation, such as investment costs or energy storage, and do not provide rigorous support for understanding which combinations of factors could underpin a leading role for wind and solar. This study addresses this gap by undertaking a systematic sensitivity analysis using a state-of-the-art energy-economic model to comprehensively evaluate the relative magnitudes of five key drivers that may influence future wind and solar deployment in the United States. We find future wind and solar capital costs and carbon policy are the dominant factors, causing the average wind and solar share to vary by 38 and 31 percentage points, respectively. Transmission and storage availability have much smaller effects, causing the average share to vary by no more than 15 and 5 percentage points, respectively. No single factor unilaterally determines wind and solar deployment. The variable renewable share of electricity generation never reaches 100% nationally in any scenario even with low-cost storage, as decreasing marginal returns at higher deployments eventually outpace cost reductions. Average wind and solar shares and ranges of possible outcomes are higher in this study relative to recent multi-model comparison studies due to lower renewable costs and the potential for more stringent policies. Understanding drivers and barriers to renewable deployment has important ramifications for technology developers, infrastructure, market design, and policymakers, and this research provides insights as to which combinations of drivers lead to the greatest share of economic wind and solar deployment and why.

Introduction
Much has been made of the potential for variable renewable energy resources like wind and solar to supply low-emissions electricity at lower costs than conventional technologies such as natural gas and nuclear power, leading many stakeholders to forecast deep wind and solar penetration in the future. Energy-economy models of the electric sector have been applied to this question (Bruckner et al 2014, Luderer et al 2017, Bistline et al 2018), but these studies disagree about the possible future shares of wind and solar (see SI appendix, figure 1, available online at stacks.iop.org/ERL/14/124001/mmedia). While some differences can be attributed to variation in model structure (Cole et al 2017, Santen et al 2017, Mai et al 2018) and input assumptions (Bistline 2015, Sherwin et al 2018), these studies all feature limited sets of scenarios, and thus offer limited insight as to which of many potential economic factors (e.g. declining renewables costs, operating costs of conventional technologies, energy storage availability, policy support) are driving wind and solar penetration. Nor are these studies able to assess the relative magnitude of the impact of these factors (SI appendix, section S1).

Many existing studies of high wind and solar penetration assess the role of a couple of drivers in isolation or with a limited number of joint sensitivities (e.g. Fell and Linn 2013, Shearer et al 2014, Hirth 2015, MacDonald et al 2016, Craig et al 2018, ...
Eshrangi et al (2018), Sepulveda et al (2018), as shown in SI appendix, table 1. Although these one-way sensitivities are valuable ceteris paribus experiments, they do not comprehensively assess the relative impact of a range of factors by jointly varying all drivers simultaneously. Other studies use modeling frameworks that focus on system operations and technical feasibility rather than economic investment (e.g. Lew et al 2010, Mai et al 2012, Jacobson et al 2015), which means that results are predicated on exogenous deployment forecasts or limited explorations of possible uncertainties. Multi-model comparison studies illustrate how insights about wind, solar, and other generation technologies compare across models (Kriegler et al 2014, Luderer et al 2017, Pietzcker et al 2017, Bistline et al 2018, Mai et al 2018); however, these studies do not offer controlled experiments across a range of economic drivers, as they typically focus on policy-related questions and sensitivities. As described in SI appendix, section S1, these multi-model studies use outdated cost assumptions for wind, solar, and storage (which likely understate future deployment) and employ models that may not adequately account for salient economic features of variable renewables. Finally, the economic literature that discusses drivers of wind and solar deployment almost exclusively uses stylized models to introduce qualitative takeaways about competitiveness rather than state-of-the-art electric sector capacity planning and dispatch models to provide more quantitative insights (e.g. Borenstein 2012, Baker et al 2013). No study has yet comprehensively assessed the economic potential of wind and solar penetration under many prospective drivers in a consistent framework by jointly varying these factors.

This paper addresses these gaps by evaluating drivers of future wind and solar deployment in the United States and their relative importance using a systematic scenario analysis of technology, market, and policy assumptions and detailed national energy-economic model. Understanding the potential role and contribution of wind and solar is a key strategic question for stakeholders and has important implications for the pace and extent of decarbonization. We consider five key drivers of deployment simultaneously, a broad range of possible realizations for each driver (including boundary cases such as unlimited transmission across regions), and analyze all combinations of these factors to provide a comprehensive evaluation of wind and solar economics. By examining hundreds of scenarios, each comprising a different combination of assumptions, our analysis can help to identify the potential economic penetration of wind and solar under a variety of conditions. As described in the next section and SI appendix, section S1, another novel feature of this analysis is the use of a state-of-the-art capacity planning and dispatch model that accounts for spatial and temporal variability, transmission and trade across regions, and energy storage investment and operations.

Analytical approach

The analysis uses the US Regional Economy, Greenhouse Gas, and Energy (US-REGEN) modeling framework to understand the relative importance of drivers to wind and solar penetration. US-REGEN is an economic capacity planning and dispatch model of the US electric sector and uses an innovative algorithm to capture the joint variation in load, wind, and solar output in a multidecadal capacity planning model (Blanford et al 2018). These unique features allow US-REGEN to evaluate how the cost of variable renewable technologies compares with their (declining) value, which can change in different locations, times, and deployment levels and can be difficult to capture in models with lower temporal resolutions (Cole et al 2017). All versions of US-REGEN represent the full spectrum of time-series variability to capture periods when, for instance, load is high and renewable output is low and periods when load is low but renewable output is high. Incomplete representations of this covariation can misvalue system resources (Merrick 2016, Blanford et al 2018). US-REGEN makes linked decisions about new generation investments and hourly system dispatch and co-optimizes transmission investment and trade. Generation technology costs come from EPRI’s Integrated Technology Generation Options report with more frequent updates for technologies like solar and wind (Electric Power Research Institute 2017a). As discussed in SI appendix, section S2, wind and solar resource potentials as well as hourly wind speed, solar irradiance, and output profiles are location-specific across a range of technologies and are based on analysis and data from EPRI, AWS Truepower, and NASA’s MERRA-2 dataset. The existing fleet is represented but subject to age limits (nuclear and coal units have 60 and 70 year lifetimes, respectively) and can retire at any time when going-forward costs exceed revenues. Load growth projections are taken from the US Energy Information Administration’s Annual Energy Outlook 2017 (US Energy Information Administration 2017).

We perform a sensitivity analysis varying each of the following five drivers to understand which factors, or combinations of factors, encourage or limit long-run economic wind and solar penetration under a variety of conditions.

1. Declining investment costs of new wind and solar (figure 1): the magnitudes of capital cost declines across the four sensitivities include a case where costs are held at current levels (‘Flat’), a case with reference wind and solar cost declines of 18% and 54% respectively by 2050 (‘Ref’), and two more aggressive scenarios with 40% and 80% lower costs relative to the reference scenario over time (‘Ref-40%’ and ‘Ref-80%’).
2. Natural gas price, which is a key driver of operating costs of gas-fired technologies: this analysis uses three stylized sensitivities with flat gas prices (in real dollar terms) across time at $4, $6, and $8 per MMBtu.

3. Potential for new inter-regional transmission: the three transmission sensitivities include a ‘Reference’ or ‘best guess’ scenario where the model makes economic decisions about transmission expansion and trade based on elicited transmission costs and wheeling charges (Electric Power Research Institute (2018a) and SI appendix, section S3). The other two scenarios offer stylized bookends; the ‘Fixed’ scenario assumes that transmission capacity and trade flows are fixed to base year levels, while the ‘Unlimited’ scenario sets all costs of new transmission investment and wheeling charges to zero.

4. Availability of low-cost energy storage: two sets of sensitivities were conducted, one with existing pumped hydro storage only and a second with low-cost battery storage with values near the bottom of the literature range (SI appendix, figure 5).

5. CO₂ policy: a reference or business-as-usual scenario does not include additional carbon policies, and a deep decarbonization scenario includes a cap on CO₂ emissions of 95% by 2050 relative to 2005 levels.

By bringing together a range of the most often considered sensitivities to renewable penetration in a single framework using a detailed US capacity expansion tool, we can comprehensively address questions about the potential drivers and limiters of wind and solar. Beyond the many combinations of outcomes for the five core economic drivers, we also conduct focused side cases to consider the availability of nuclear generation, availability of carbon capture and storage (CCS) technologies, and cases where renewable generation profiles are constant. The last case provides insights about how variability impacts the value and deployment of renewables and illustrates a common misperception about interactions between energy storage and wind and solar from levelized-cost metrics.

Note that the stylized assumptions here are intended to answer the specific questions of the study; as always, scenarios should not be interpreted as predictions of likely future events or outcomes. More information about model structure and scenario assumptions are provided in the SI appendix, sections S2 and S3.

Integral to the analysis is a framework for modeling renewables using a US-focused, long-term capacity planning model with detailed operations. The literature has demonstrated the importance of using models that capture the declining economic value of variable renewable energy at higher penetration levels (Hirth 2013, Blanford 2015, Gowrisankaran et al 2016, Bistline 2017, Wiser et al 2017). Figure 2 shows the economic intuition for how the equilibrium variable renewable share (‘Share 1’) jointly depends on the slopes of the marginal value curve (‘Value’) and marginal cost curve (‘Cost 1’), which assumes that costs decline in deployment (Nordhaus 2014). If costs decline due to innovation, the shift in the cost curve...
from ‘Cost 1’ to ‘Cost 2’ consequently increases variable renewable deployment to ‘Share 2.’ The value curve also may shift with alternate assumptions about transmission and energy storage, which would yield different estimates for variable renewable energy shares\(^2\). These stylized dynamics demonstrate how unilateral variable renewable technological portfolios are unlikely to materialize due to economics alone but also how decreasing returns do not imply that the role of variable renewable energy will be limited. Since the value drop is a complex and endogenous function of the system state, capturing decreasing returns in a modeling framework requires tools like US-REGEN with sufficient levels of detail to capture the dynamics of investment and operations.

### Impacts of variable renewable energy capital costs

To isolate the impacts of specific drivers, scenarios exclude existing incentives for renewables (e.g. federal tax credits and state-level mandates) or state-level carbon policies (e.g. California’s cap-and-trade or RGGI). Since renewable standards are the most prevalent state-level policy tools and essentially create a lower bound on deployment, this omission likely does not change the qualitative insights and makes it easier to identify underlying drivers of outcomes, though state-level results should not be interpreted as policy analysis. Additional information about reference assumptions are provided in SI appendix, section S2.

The key metric evaluated in this analysis is the share of wind and solar as a percentage of national electricity generation. Figures 3 and 4 suggest that future wind and solar capital cost reductions (shown in figure 1) relative to cost declines for other technologies are the most significant driver of long-run renewable penetration in the US. As costs decline, figure 4 shows how the mean national wind and solar generation share increases from 32% to 70% (varying by 38 percentage points), and the interquartile range decreases from 77 percentage points to 20. If very low capital costs are achieved, at 52% and 91% below today’s costs for wind and solar, respectively, then there is no combination of drivers that results in less than 45% wind and solar share, and the majority of scenarios see greater than 70% wind and solar share.

#### Sensitivity to operating costs of other technologies

No single driver is as impactful as the capital cost of wind and solar technologies, although wind and solar generation shares over 80% can also arise even if the capital costs are high; notably when a CO\(_2\) policy is in place and new nuclear and CCS technologies are unavailable, as discussed later. In addition to wind and solar capital costs and CO\(_2\) policy, natural gas prices (which greatly affect the operating costs of gas-fired generation) are another driver of variable renewable deployment. For the gas price trajectories considered in the analysis ($4, $6, and $8 per MMBtu, shown in SI appendix, figure 9), cost declines for renewables and gas prices jointly determine wind and solar penetration. At one extreme, low gas prices create headwinds for other generation technologies, as shown in figure 3. At the other extreme, high gas prices improve the competitiveness of renewables, and could result in wind and solar supplying over half of electricity even with modest cost declines. Moving from $6 to $4 gas lowers wind and solar generation shares between 10 and 26 percentage points, while moving from $6 to $8 gas increases share between 4 and 18 percentage points (figure 3). Examples of generation mixes over time are shown in SI appendix, section S4.C.

Overall, figure 4 shows the wide range of wind and solar shares depending on assumed cost declines, gas prices, storage, and transmission. Figure 4 depicts...
wind and solar generation shares across all five drivers, with each bar depicting the potential range of shares when holding a single factor fixed and varying all others between their respective values. Even without new storage, new transmission, or policy, wind and solar penetration could reach 59% of generation at a national level given very low costs and high gas prices. High variable renewable shares do not necessarily require energy storage in these scenarios, since system balancing is achieved through a portfolio of resources like dispatchable fossil units (often with lower capacity factors), hydropower, transmission, system operations, and curtailments.

Note that the central value and range of future wind and solar shares shown in figure 4 are notably higher than recent multi-model studies for the US (SI appendix, figure 1). The higher penetration across ‘current policy’ and decarbonization scenarios is due in part to the lower projected wind and solar costs (and wider ranges) used in this analysis and to the more stringent policy cases investigated.

The wind and solar share of electricity generation is far from 100% across most scenarios and regions, largely due to the decreasing value of variable renewable output as wind and solar capacity increases. Figure 6 shows the decline of regional revenues of
wind and solar as penetration increases across a variety of conditions. Other studies have discussed the drivers and impacts of decreasing returns in observed and modeled systems (Hirth 2013, Blanford 2015, Gowrisankaran et al 2016, Bistline 2017, Wiser et al 2017), but this analysis underscores how dynamics like seasonal resource variability contribute to steep value declines with higher wind and solar shares, even with optimistic assumptions about the costs of backup resources with low utilization rates (Shaner et al 2018).

National electric sector CO2 reductions across scenarios (relative to 2005 levels) are shown in figure 5. Except for the second-to-right bar, half of the data in each plot are scenarios that include the 95% cap policy, thus skewing the distribution of CO2 reductions. For scenarios without the 95% cap policy, CO2 emissions reductions largely track renewable penetration and demonstrate tradeoffs between renewables and gas, especially since many coal and nuclear plants have retired in these scenarios by 2050. The CO2 policy leads to more significant and predictable emissions declines by design, as few scenarios without policy achieve 80% emissions reductions even with widespread wind and solar deployment. Of the five drivers included in this analysis, the variation in CO2 outcomes narrows most across the CO2 policy, variable renewable cost, and gas price sensitivities. Transmission and energy storage have more limited impacts on CO2 emissions, though both can lower system costs (SI appendix, figure 18).

Implications of transmission expansion

A third driver is inter-state transmission, which can potentially enable geographical pooling of resources and mimic ‘shifting’ renewable generation across time zones. We find that, with reference costs for new transmission and limited siting constraints, the option to build such transmission incents relatively little incremental renewable generation compared with the other drivers. Figure 3 indicates that allowing long-distance transmission expansion in the ‘Reference’ scenario increases wind and solar penetration up to 12 percentage points relative to the ‘Fixed’ scenario with base year capacity but barely changes variable renewable shares when costs do not decline rapidly. At the opposite extreme, the assumption of unlimited costless transmission across the contiguous US (a ‘copper-plate’ system) leads to an increase of 10–20 percentage points in the variable renewable share. Note that, even though transmission and storage assumptions are not the single biggest drivers of wind and solar deployment, these resources may have high values to the system as a whole (as shown in SI appendix, figure 18).

The role of energy storage

Energy storage is one option to shift the profile of renewable generation, by potentially charging when renewable generation is high and load is low, and discharging when renewable generation is low and load is high. However, storage can be a capital-intensive technology and incurs operational losses. We find that, assuming improvements in losses (91%}

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3 ‘Ref’ refers the reference assumptions, ‘Cap’ is the CO2 cap scenario with a 95% reduction by 2050, and ‘Lim’ is the limited technology sensitivity where new nuclear and CCS are not available.

4 Additional model detail and scenario assumptions are discussed in SI appendix, section S2.
roundtrip efficiency) and capital costs ($50/kW and $100/kWh), low-cost energy storage does not greatly increase total renewable penetration, as shown in figure 4 and the lower panel of figure 3. Figure 3 indicates that extensive battery storage deployment only increases total renewable deployment between 0 and 12 percentage points (with values that generally increase with lower wind and solar capital costs and higher gas prices). The mean wind and solar share only increases by five percentage points between the reference and low-cost energy storage sensitivities. Although its does not have large impacts on total variable renewable penetration, energy storage does change the ratio of installed solar to wind capacity (SI appendix, figure 17) and lowers system costs (SI appendix, figure 18). Energy storage reduces electric sector costs most under conditions with stringent CO₂ policies, high gas prices, and high renewable deployment. Cost reductions from energy storage deployment are often larger than those from increased transmission (SI appendix, figure 18), though these magnitudes are conditional on the specific assumptions in this analysis.

Low-cost energy storage is neither necessary nor sufficient for higher wind and solar penetration, as storage can be valuable at lower variable renewable shares (e.g. for regions with high shares of inflexible generation and high gas prices) and is not necessarily economic under some conditions with higher shares (e.g. for wind-heavy mixes in areas with extensive transmission). Rather, storage is a facilitative condition for higher wind and solar penetration and ultimately may provide value to the system through a range of services aside from variable renewable integration (Electric Power Research Institute 2017b, Balducci et al 2018, He et al 2018, Arbabzadeh et al 2019). Nevertheless, it is important to note that, given the assumptions in this analysis, battery storage is deployed in all scenarios with wind shares higher than 50% and solar shares above 20%. Ultimately, there are many options for balancing and integrating variable renewables, and the effectiveness of alternatives should be evaluated under different assumptions about cost, availability, and political feasibility.

Figure 6 shows the relationship between revenues to wind and solar generators and their penetration by region and scenario. Value deflation (i.e. decreasing economic returns to wind and solar as their capacity increases) is observed in the analysis across a wide range of regions, technologies, and scenarios, though the magnitudes vary. Low-cost energy storage may help to soften the impact of decreasing returns but will not fix it, especially since energy storage technologies themselves also exhibit value deflation (Blanford 2015, de Sisternes et al 2016, Bistline 2017, Denholm and Mai 2019). The primary causes of value deflation are spatial and temporal variability of wind and solar output, correlated output across successive wind and solar installations, declining capacity credit (SI appendix, figure 12), and higher curtailments, among others (Mai et al 2018).
Confusion about the role of energy storage in driving variable renewable deployment could be due in part to inaccurate mental models of interactions between these technologies. Energy storage is sometimes described as removing the temporal variability (i.e. flattening the output) of wind and solar and/or making hybrid systems fully dispatchable resources. We demonstrate the significant differences between storage and ‘flat output’ by conducting an additional sensitivity that examines the impact of constant wind and solar availability, where the hourly profiles are assumed to be constant at their annual average. This setup mimics levelized-cost metrics that are sometimes used as summary statistics for technological competitiveness despite their significant shortcomings (Joskow 2011). SI appendix, figure 11 demonstrates how wind and solar penetration, when modeled with flat profiles, are significantly higher than comparable scenarios with their actual shapes. These results, when compared to our variable renewable scenarios with storage, highlight how storage (even with cheap batteries) is quite dissimilar from a hypothetical scenario with constant renewable output, as neither storage nor transmission surmount the hourly profile correlation challenges between variable renewable energy and load. Thus, inaccurate intuitions about the function of energy storage and levelized-cost metrics may be contributing to the misperception of impacts of storage on wind and solar shares. These results also underscore the importance of the modeling platform for evaluating variable renewable energy economics and specifically of capturing the joint temporal variability of load and renewable generation (Blanford et al 2018).

Impact of CO₂ policy

Stringent carbon policies also may have significant impacts on wind and solar penetration if enacted by raising the costs of emissions-intensive generation and shifting the incentives to adopt low-carbon technologies like renewables, nuclear, and CCS. Figure 4 suggests that policy drivers can be nearly as important as capital cost reductions in determining wind and solar deployment (causing the average wind and solar share to vary by 31 and 38 percentage points, respectively), especially in reducing the likelihood of low variable renewable energy states-of-the-world. Although CO₂ policy generally boosts wind and solar shares, the impact depends jointly on variable renewable cost reductions and the availability of other technologies (figure 7). A ‘Limited Portfolio’ sensitivity, where new investments in nuclear and carbon-capture-equipped generators are prohibited due to political or technological factors, does not materially change wind and solar shares without policy, as the prohibited technologies are not in-the-money apart from high gas price scenarios with limited wind and solar cost reductions. However, restrictions on technological availability greatly impact generation shares and costs under the 95% cap, as shown in the bottom panel of figure 7.⁵

⁵ Note that, to simplify this analysis, investments in geothermal, hydro, and biomass are not included. Although this omission would not materially impact insights across most scenarios, the 95% cap scenario without nuclear and CCS would likely include some generation from these omitted technologies.
Regional variation

Results in earlier sections focus on national impacts, but there is wide variation in regional wind and solar buildouts depending on market conditions. Figure 8 compares wind and solar generation shares at the national and regional levels across different variable renewable costs and gas price scenarios. Regional wind and solar deployment can be considerably higher or lower than the national average, which suggests that analysis that does not capture regional heterogeneity or that only reports national summary statistics (e.g. integrated assessment models) may understate uncertainty in possible outcomes. The variance across scenarios increases as costs initially decline but then decreases at ultra-low capital costs.

Figure 9 shows the relationship between wind and solar generation shares and declining costs for specific regions (regions are defined in SI appendix, figure 3) and highlights how the supply responsiveness varies across regions. Regions with higher quality wind resources like NW-Central and Mountain-N tend to have higher price elasticities of supply, and as wind and solar costs decline, these regions tend to become net exporters. The national wind and solar share increases most between the ‘Ref’ and ‘Ref-40%’ cost scenarios, but regional magnitudes vary.
Discussion

Much attention has been paid to the dramatic fall in renewable capacity costs in the last decade, with many commentators citing this decline as reason to predict large quantities of new renewable generation. This research aims to quantify how power sector incentives for wind and solar investments change under a range of possible drivers.

Using a detailed electric sector capacity planning and dispatch model, this analysis suggests that the largest drivers of wind and solar penetration in the US are the extent of future cost reductions and carbon policy, though a wide range of outcomes are possible nationally and regionally. No single factor determines the future deployment of wind and solar, as low costs are not a guarantee of high deployment and deployment may be high even at higher costs. Although future cost reductions for renewables are a key driver, the extent of market diffusion would remain uncertain even with perfect cost forecasts, as deployment is a complex function of many factors and requires detailed analysis to evaluate. The range of possible outcomes under different settings suggests the importance of joint scenario analysis across uncertainties in the decision-making environment (Diamant et al 2018). Average wind and solar shares and ranges of possible outcomes are higher in this study relative to recent multi-model comparison studies due to the lower renewable costs and potential for more stringent policies considered here.

The variable renewable energy share of future electricity generation is far from 100% across scenarios and regions even with low-cost battery storage and no explicit constraint on instantaneous non-synchronous generation, as decreasing marginal returns at higher deployment eventually outpace cost reductions. 100% variable renewable outcomes might be technically feasible but would require many assumptions to be true. The importance of market value (e.g. policy impacts on revenues, sensitivity to fuel prices) and decreasing economic returns in driving wind and solar deployment suggests that solely cost-based analysis of energy system futures cannot meaningfully compare the economic competitiveness of different technologies.

Downside risk for new renewables investments are a lack of carbon policy, low gas prices, and lack of future cost reductions. Changes in renewable capital costs and the operating costs of competing technologies can drive significant shifts in wind and solar penetration, particularly if both happen in tandem. Energy storage and transmission have more limited impacts on variable renewable deployment and are most impactful when penetration exceeds 40% of generation, which can boost wind and solar shares between 0 and 20 percentage points. The system value of these resources may be significant even if storage and transmission are not the largest drivers of incremental wind and solar investments.

Understanding relative magnitudes of drivers for wind and solar is a key strategic question for many stakeholders and has important implications for the pace and extent of decarbonization. This analysis indicates potential barriers where further technology RD&D and analytical tools are needed and can be used to identify where additional RD&D can be most effective. The analysis also suggests which model capabilities are most significant for understanding the role of variable renewable energy, with the representation of temporal variability being the most important, and the representation of storage and transmission being less critical, as these technologies have smaller impacts on renewable shares but may have a more significant impact on overall system cost.

Future work should investigate how market design and structural changes to the power system can ensure adequate returns for investment while integrating higher wind and solar shares. Additional challenges include coordination with other parts of the energy economy and consumers, including potential opportunities and challenges associated with end-use electrification and economy-wide deep decarbonization (Electric Power Research Institute 2018b). Future analysis should investigate energy storage, impacts of other policy instruments, intra-regional transmission constraints, and financing in greater detail.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available for legal and/or ethical reasons.

Author contributions

JETB and DTY designed research, performed research, analyzed data, and wrote the paper.

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