

State-led climate action can cut emissions at near-federal costs but favors different technologies

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This manuscript has been previously reviewed at another journal. This document only contains information relating to versions considered at Nature Communications.

This file contains all reviewer reports in order by version, followed by all author rebuttals in order by version.

Version 0:

Reviewer comments:

Reviewer #1

(Remarks to the Author)

Technological Pathways Diverge Under State versus Federally Led Decarbonization

Key results

This manuscript forecasts Greenhouse Gas emissions from six sectors in twenty-three states and compares this to a national action scenario. The authors aim to understand the overall decarbonization potential emerging from the twenty-three states where the political environment is more likely to pursue net zero emissions by 2050. The analysis suggests that a bottom up decarbonization effort would rely on different approaches to decarbonization relative to a national approach. In particular, the authors suggest their models indicate state led decarbonization would shift emissions to the electric sector, while national action distributes carbon emissions across sectors.

Validity

It is an interesting analysis on an important topic. That noted, I have some concerns about the manuscript. It isn't clear why the author's identified the climate engaged states the way they did (constructing a 5-point scale. Certainly, the states that are noted as climate engages seem to have face validity, but why note use something like Climate X Change and their state policy tracker? This would provide a more concrete indication of a state's commitment to net zero.

Significance

The results of the modeling effort – as presented in the paper – are not surprising. There is no theoretical reason to think a state government, acting without a federal legislative backdrop, would pursue the same policy choices if consistent federal action were a reality.

So while this is an important area to examine, I think the contribution could be strengthened.

Data and methodology

I remain unconvinced of the forecasting despite the intuitive findings. Part of my skepticism is rooted in my understanding of state government. It is one thing to adopt a goal, and quite another endeavor to implement policy – particularly when there are powerful forces and path dependency that help maintain the status quo. California is already not meeting its GHG emission goals, so the implementation of the state's climate policy has not yielded the expected results.

I understand the need to simplify models and make assumptions to forecast out, and yet, it isn't clear that the model accounts for shifting demand based on population migration. The analysis focuses on the production side of limiting emission and more justification of this would add strength to the paper. The sectors used in the analysis do not include agriculture – despite the fact that agriculture has a higher emission profile than commercial or residential sectors. While the authors highlight the importance of electricity generation, they have not considered the diversity of power regulations – even across the twenty-three states (and more broadly across the country).

Analytical approach

I have not worked with this type of open source forecasting model, so I am unable to comment on the specifics.

Suggested improvements

Revisit the construction of climate engaged states and confirm if using data from Climate X Change's state policy tracker yields similar twenty-three states. Provide more clarity about your modeling choices and constraints.

Clarity and context

The manuscript is at times difficult to follow. The authors group most states into regions but separate out California and Texas. This is not intuitive – despite the fact that these states are critically important for climate goals. This approach makes seeing your full results and grasping them more challenging than it should be. The figures in the paper are difficult to read and the similar color schedule between Figure 2 – which reports emission changes by geography, and the other figures (3, 4&5) report emission changes by sector. Using a different color scheme would help distinguish the figures.

(Remarks on code availability)

Reviewer #3

(Remarks to the Author)

The article "Technological Pathways Diverge Under State Versus Federally Led Decarbonization" contrasts two optimization model results to explore the impact of different jurisdictional approaches to climate mandates. The premise is grounded in the United States' federal system, where states have the authority to establish their environmental policies. While the two scenarios do not correspond actual jurisdictions policies, the authors pose an intriguing question: what is the difference between addressing climate change at the national level versus placing the burden on the most climate-progressive states? The study reveals distinct mitigation approaches deployed nationally, with minimal cost differences.

However, the article does not account for the actual variations in state policy portfolios within the U.S., nor do the scenarios align with the federal government's goal of achieving net-zero emissions by 2050. Despite these limitations, the authors' rationale for conducting this analytical exercise remains valid. The analysis is precise, the results are well-presented, and the evidence supports the article's conclusions. For these reasons alone, the paper should be considered for publication.

That said, several recommendations could enhance the article's value, particularly for policy-oriented readers interested in the implications for climate federalism in the U.S. and other federalist systems, such as Brazil or Canada. Additionally, there are a few analytical and discussion-related issues that warrant attention.

- 1. Federalism and Polycentricity:** The authors discuss federalism and polycentricity debates but predominantly focus on federalism throughout the article. The discussion of polycentricity seems misaligned with the paper's objectives, as the concept usually involves a broader range of actors and institutional arrangements than what is considered here (NGOs, cities, academia, etc). The federalism framework alone suffices for this study. Still, the authors could discuss further the nature of US federalism concerning different areas of governance that are relevant to the study.
- 2. 2050 Emissions Benchmark:** The article establishes a reference emissions reduction benchmark for 2050, but this benchmark falls significantly short of the national net-zero target. It is roughly half of current emissions, which on a per capita basis would likely still exceed today's global average. This critical detail should be clearly stated in the Abstract and early in the Introduction, as it could significantly alter the study's conclusions if the optimization required achieving more ambitious decarbonization levels.
- 3. State Divisions Based on Political Variables:** The authors define state divisions using political variables, referencing one source (Ref 28). It would be beneficial to include references to states with net-zero targets. This would not only aid readers but also justify the methodology of inclusion of states in the "green" category beyond the current net-zero targets.
- 4. Language and Model Descriptions:** The article uses two distinct approaches to discussing findings—one focused on model constraints and results and another that places agency on regions or states by attributing "strategies" or "pursuits" to them. The latter approach is misleading, as it implies that the model's results reflect actual policy decisions, which is not the case. For example, the subtitle "2.4" and sentences like "California and the Northeast rely on different power generation strategies" (line 264) should be revised to avoid this confusion.
- 5. Conclusion and Policy Implications:** The conclusion highlights the relevance of state action in creating a more resilient climate policy system in the U.S., particularly given the uncertainties in national politics. It also touches on issues such as emissions leakage and regional differences in mitigation strategies. The authors should explore the possibility of a third scenario in which distinct state-based systems of climate action cater to regional technological priorities in addition to the national and state-led models discussed.
- 6. Temporal Differences and BECCS:** The article focuses on results for the year 2050, but there appear to be significant differences over time that do not simply follow a linear progression. This is particularly evident in Figure 7. Additionally, the prominence of BECCS in the Southeast as early as 2025 is striking and warrants discussion in the context of carbon management strategies.
- 7. Transmission Capacity and Carbon Leakage:** The article provides valuable insights into transmission capacity and

carbon leakage. A technical point worth addressing is the exclusion of Canada from the study, given its potential relevance to regional interconnections. This exclusion presents an opportunity to discuss how the issue of carbon leakage might evolve in light of U.S. government plans to enhance regional interconnections.

8. Lastly, the sentence in line 513—"Ultimately, we find moderate emissions reductions from stylized subnational action, unable to meet larger stated federal ambitions"—is somewhat misleading. The method was not designed to match the federal net-zero ambition, so this should not be framed as a finding.

(Remarks on code availability)

Reviewer #4

(Remarks to the Author)

The authors critically relied on the political indicator (0-5) in their analysis to assess the impact of state-level governance on decarbonization projections and the types of technology to deliver them. While some may criticize that the state-level governance structure (or political opportunity for the net-zero outcomes) is too broad a factor that shapes the actual deployment of low-carbon technologies by actors within each state jurisdiction, I believe this approach is still useful in that it well serves the authors' main objectives to compare the implications of state-led and federal-led decarbonizations.

My main concern, however, pertains to the meaning of their political indicators and their implications for their analysis.

I believe the state-level heterogeneity is something that this paper should emphasize and take advantage of rather than downplay. Yet, this paper seems to downplay it for several reasons.

First, five elements in their political indicator are highly intercorrelated. This means that there are few states in the middle (say, those that score around 3), and while a large number of states will score either lower than 1 or higher than 4, their heterogeneity may be under-evaluated.

Even after assigning scores to each state based on five political indicators, the authors grouped them into nine regions rather than conducting a state-level analysis. This may further mask the state-level differences in both the governance structure and its decarbonization and the use of technology. Why did the authors conduct the regional analysis rather than the state-level?

Also, the choice of these five elements seems a bit arbitrary. What in the previous literature makes the authors decide on these five elements? Is binary indicator appropriate for Renewable Portfolio / Clean Energy Standard or Greenhouse Gas Reduction Goal? What if a RPS or reduction goal is voluntary as opposed to mandatory? What is the risk of pooling reduction goals of different target years and reduction levels?

After assigning states into nine regions, the authors stated that Temoa model run yielded different decarbonization constraints, ranging from 1.6% to 100%. However, nowhere in the paper or supporting information did the authors explain these steps in detail. How did the model render different levels of decarbonization constraints across nine regions based on the political indicator scores of affiliated states?

In their revised manuscript, I suggest the authors address these issues whenever necessary to better substantiate the political indicator.

(Remarks on code availability)

Version 1:

Reviewer comments:

Reviewer #1

(Remarks to the Author)

(1) What are the noteworthy results?

Yes - this revised manuscript is much improved. And given the changes in federal commitment to addressing climate change, this work takes on heightened significance. This paper analyzes forecasts the environmental implications - in terms of decarbonization approaches and resulting GHG emission reductions.

(2) Will the work be of significance to the field and related fields? How does it compare to the established literature? If the work is not original, please provide relevant references.

Yes - this is significant. It is interesting to consider that state and national approaches hold the potential to reduce the same amount of emission, but this paper highlights how states may vary sectorally in their approach to decarbonization and also

provides an opportunity to compare that sector emissions under a (unlikely) federal approach.

(3) Does the work support the conclusions and claims, or is additional evidence needed?

I think so, but this is not the kind of empirical analysis I do, so I can only state that as a general reader in that regard, the paper makes sense (set up, methods, presentation of results, discussion and conclusion make sense).

(4) Are there any flaws in the data analysis, interpretation and conclusions? Do these prohibit publication or require revision?

None that I could identify.

(5) Is the methodology sound? Does the work meet the expected standards in your field?

See comment above.

(6) Is there enough detail provided in the methods for the work to be reproduced?

Yes, I believe so. The manuscript and supplemental material seem to be sufficient. And the GitHub repository is populated with files that would support replication.

Minor point - The first sentence of the manuscript should be adjusted as the US withdrew from the Paris Climate Agreement during the early days of the second Trump Administration.

(Remarks on code availability)

Reviewer #3

(Remarks to the Author)

After reviewing the revised text and the author's response to my comments and suggestions, I am satisfied with how the authors have improved the clarity of their findings and scope of work. In particular, I appreciate the extended discussion on federalism and the opportunity they have taken to bring to the fore the centrality of states in a federal system under an anti-climate action federal Executive. The mention of contested federalism is appropriate as a concept to set the tone for the authors' analysis. Finally, the readers will benefit from clearly reading about the model results that we might find hard to achieve even though policymakers tried, like the fast deployment of BECCS.

This is an specially timely paper and I commend the authors for delivering a great piece.

(Remarks on code availability)

Reviewer #4

(Remarks to the Author)

Thank you for the opportunity to review this revised manuscript. I believe the authors have extensively responded to my earlier comments regarding the state-level vs. regional-level analysis, political indicators, and an additional explanation of how the Temoa Model works. I can now recommend the manuscript be published as it stands. Thank you very much for your great work.

(Remarks on code availability)

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General Comments

We would like to thank the editor and reviewers for their thorough and thoughtful comments. We have modified the paper to respond to these comments, as detailed below.

In addition, given the outcome of the recent presidential election in the United States, we believe that our paper has a new-found timeliness and relevance. To better communicate this relevance, we have modified some text to focus more clearly on the role and impacts that state-led decarbonization efforts can achieve, relative to federal action which is now far less likely. In addition, we have changed the title to “**When states lead the way: decarbonizing at similar costs to federal action in the absence of national policy**” to emphasize this new framing.

Beyond the edits that directly respond to reviewer comments, we made the required changes to reflect the policies of the journal, including shortening the abstract to 150 words, removing subheadings from the Introduction, and providing a new final paragraph for the Introduction that summarizes the work:

[Line 13] Abstract: “In the absence of comprehensive federal greenhouse gas mitigation policy, state-led strategies may play a pivotal role, particularly following the 2024 U.S. presidential election. Using a detailed energy system optimization model, we examine the outcomes of 23 climate-minded states pursuing net-zero emissions targets compared to a federal carbon cap achieving equivalent CO₂-eq reductions. State-led decarbonization results in distinct technology choices, a 0.7% increase in system costs, and nationwide emissions reduction of 46% — substantial, but insufficient for ambitious climate goals. This pathway relies more on electrification, with 952 TWh more generation in 2050, reallocating 17.2% of emissions to the power sector. Some regions favor solar, wind, and storage, while direct air capture emerges as critical, particularly in California and the Northeast. Inter-regional trading supports and complicates mitigation efforts, underscoring the need for careful policy design. Here we show how state-led and federal decarbonization approaches can yield differing energy portfolios to achieve similar emissions reductions.”

[Line 155] “In this work, we use the energy system optimization model Temoa to explore the technology and cost implications of state-led versus federal-led decarbonization strategies in the United States, identifying context-specific technology choices required for state-led decarbonization. We find that state-led approaches yield heterogeneous technology deployments, with increased reliance on electrification, regional expansion of renewable energy and battery storage, and a critical role for direct air capture in achieving emissions reductions. Despite these differences, the cost increase compared to the federal scenario for equivalent emissions reductions is small. Our findings highlight how shifting from uniform national policies to a state-led framework reshapes energy system outcomes, offering insights into the opportunities and challenges of achieving net-zero targets under a climate federalism paradigm.”

Reviewer #1 (Remarks to the Author):

This manuscript forecasts Greenhouse Gas emissions from six sectors in twenty-three states and compares this to a national action scenario. The authors aim to understand the overall decarbonization potential emerging from the twenty-three states where the political environment is more likely to pursue net zero

emissions by 2050. The analysis suggests that a bottom up decarbonization effort would rely on different approaches to decarbonization relative to a national approach. In particular, the authors suggest their models indicate state led decarbonization would shift emissions to the electric sector, while national action distributes carbon emissions across sectors.

It is an interesting analysis on an important topic.

We thank the reviewer for recognizing the timely significance of the topic. It is our opinion that the federalist question in U.S. decarbonization strategy is perhaps at its highest relevance. Conducting a high-level policy theory exercise using detailed capacity expansion modeling provides a key contribution to further academic exploration of the question.

That noted, I have some concerns about the manuscript. It isn't clear why the author's identified the climate engaged states the way they did (constructing a 5-point scale. Certainly, the states that are noted as climate engaged seem to have face validity, but why not use something like Climate X Change and their state policy tracker? This would provide a more concrete indication of a state's commitment to net zero.

Thank you for this comment. We took this suggestion and compared our set of states to a selection using the Climate X Change (CXC) database, finding consistent results. Specifically, to confirm that our methods are supported by robust state climate policy trackers, we compared CXC's accounting of "enacted climate policies" against our method which selected 23 "net-zero" states using a 5-point scale. According to CXC, our selected 23 "net-zero" states all had 16 or more enacted climate policies, while our 25 excluded states all had 10 or fewer enacted policies. While there is no single approach that determines ideal cut-off criteria, our approach is robust to the CXC sorting of state-level climate policy engagement, affirming our method when compared to the reviewer's suggested policy tracker.

Additional language has been included to incorporate this discussion and validation of the authors' selected indicators:

[Line 184, tracked changes version] "We identify potential net-zero states using a set of five political indicators (presented in Table 1): the adoption of a state-level Renewable Portfolio Standard/Clean Energy Standard, a greenhouse gas reduction goal, the political affiliation of the governor and legislative majority, and the presidential vote.²⁴ The selection of these political indicators follows existing policy literature identifying liberal citizen ideology and partisan control of the legislature as strong drivers of climate and energy policy adoption. The additional combination of examining both existing climate and energy policy as well as political partisan makeup further strengthens this selection. With a maximum possible score of five, a score of at least 3.0 is set as the binary threshold for states with predicted mid-century "net-zero involvement." Those at or above this score were deemed net-zero states, those below had no added carbon constraint. Based on these criteria, 23 states and the District of Columbia are included as net-zero states, shown in Figure 1.²⁵ This selection criteria and the resulting net-zero states are consistent with the set of states identified as highly involved in climate legislation in robust state-level policy trackers such as Climate X Change.²⁶ All selected net-zero states in our analysis have 16 or more climate policies enacted, as identified by Climate X Change, while all

other states have 10 or fewer such policies enacted. We acknowledge that there is no single "correct" set of net-zero states, as the enactment of any policy is subject to uncertain passage. In addition, the composition of this group of states is likely to change over time in response to evolving political dynamics, shifts in citizen preferences, and the broader policy landscape."

The results of the modeling effort – as presented in the paper – are not surprising. There is no theoretical reason to think a state government, acting without a federal legislative backdrop, would pursue the same policy choices if consistent federal action were a reality.

So while this is an important area to examine, I think the contribution could be strengthened.

Thank you for raising this point. It was not our intention to suggest that states would pursue identical policy choices relative to federal action. Instead, we were endeavoring to shed light on how a singular goal – namely the reduction of greenhouse gas emissions – could be pursued and achieved (or partially achieved) at different administrative levels, but at different costs and technology choices given local resources and constraints. Some text where we make aim to make this clear:

[Line 104] "Based on the potential for subnational climate leadership, we ask in this research: As compared to federal action, what are the technology and cost implications of state-led decarbonization efforts?"

[Line 114] "These results, however, will shed light on how a singular goal – namely the reduction of greenhouse gas emissions – could be pursued and achieved (or partially achieved) at different administrative levels, but at different costs and technology choices as driven by local resource availability and other constraints."

I remain unconvinced of the forecasting despite the intuitive findings. Part of my skepticism is rooted in my understanding of state government. It is one thing to adopt a goal, and quite another endeavor to implement policy – particularly when there are powerful forces and path dependency that help maintain the status quo. California is already not meeting its GHG emission goals, so the implementation of the state's climate policy has not yielded the expected results.

We agree that a healthy skepticism of achieving net-zero emissions through policy implementation is warranted. This is true at the state-level, federal-level, and national-level. That said, the urgency of addressing climate change will require pursuing solutions that are challenging to implement. The scenario design is not intended to suggest that implementation of state-level policies will not be met with fierce opposition. We had added the following text to reflect this sentiment.

[Line 585] "This stylized subnational action also fails to meet larger stated federal ambitions. Furthermore, even this reduced mitigation level will be challenging to successfully execute. As a result, we suggest this paper's National Action scenario be a means to identify where future federal intervention may be most cost-effective and politically resilient."

I understand the need to simplify models and make assumptions to forecast out, and yet, it isn't clear that the model accounts for shifting demand based on population migration.

We thank the reviewer for providing insight into ways to strengthen the communication of the research approach. The input assumptions for the model rely on the best available spatially-resolved demand forecasts for energy services, which do reflect shifting regional demands. We updated the text to reflect this:

[Line 649] "...input data included projected end-use service demands reflecting regional and temporal trends..."

In the Supporting Information, we added substantial detail:

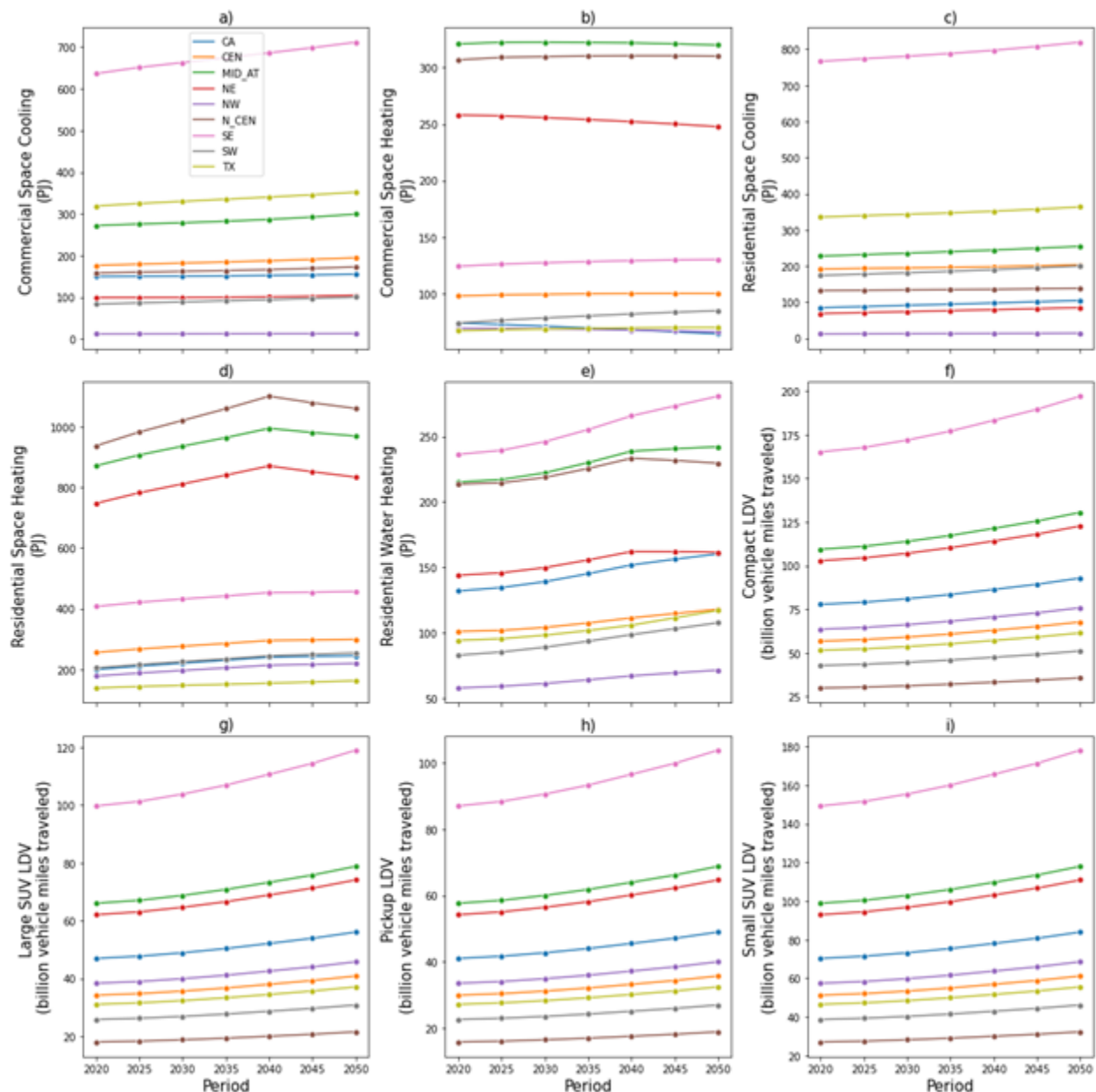


Figure S1: Service demands exogenously specified for a) commercial space cooling, b) commercial space heating, c) residential space cooling, d) residential space heating, e) residential water heating, f) compact light duty vehicles (LDV), g) large sport utility vehicles (SUV) LDV, h) pickup LDV and i) small SUV LDVs. These represent 9 of more than 70 demands exogenously enlisted in the database. Demands for the commercial and residential sectors are adopted from National Renewable Energy Lab's (NREL) Electrification Futures Study (EFS). Demands in the transportation sector are extracted from NREL EFS and U.S. Environmental Protection Agency's nine-region market allocation database (MARKAL).

The analysis focuses on the production side of limiting emission and more justification of this would add strength to the paper.

Thanks for the comment. We added detail and justification in the Methods section:

[Line 635] “Our approach identifies least cost options to meet exogenous end use service demands, such as vehicle miles travelled by vehicle class. The decisions available within the model include shifting technologies with improved efficiency or lower emissions to meet the end use service demands. Mitigation measures that reduce the levels of service provided (e.g., telecommuting that reduces vehicle miles travelled) are not explicitly considered in our analysis, but these measures are unlikely to provide significant mitigation potential compared to supply-side or efficiency improvements.”

The sectors used in the analysis do not include agriculture – despite the fact that agriculture has a higher emission profile than commercial or residential sectors.

As an energy system optimization model, our approach does exclude some aspects of the agricultural sector, which is common practice for these models. According to the U.S. Greenhouse Gas Inventory, however, the agricultural sector has lower emissions than the residential and commercial sectors when one considers the impacts of electricity emissions. Regardless, the following text was added:

[Line 641] “The scope of our analysis broadly covers emissions from the energy sector including fossil fuel combustion in agricultural processes, but does not include emissions from some agricultural activities such as soil management, enteric fermentation from livestock, and manure management, which were responsible for 9.4 percent of the gross U.S. greenhouse gas emissions in 2022.⁴² Expansion of the scope to include these emissions would provide additional mitigation opportunities and challenges in achieving net-zero emissions.”

While the authors highlight the importance of electricity generation, they have not considered the diversity of power regulations – even across the twenty-three states (and more broadly across the country).

A cost-minimization approach to power system expansion and operation is a standard method to represent the decision making across different power sector regulatory structures. In both regions with a single generation utility and energy markets, there is an expectation of dispatching power plants based on lowest

cost. This cost-minimization logic also applies to long-term investment decisions, regardless of whether the service territory has a capacity market or is served by a regulated utility.

Our model does reflect some of the heterogeneity in state and regional policies that impact power generation. For example, renewable energy mandates as driven by state-level Renewable Portfolio Standards are represented as generation constraints and the Cross-State Air Pollution Rule (CSAPR) is reflected as region-specific emissions constraints. (Text in manuscript shown below.) Given that our model has a full energy system representation, however, there is a direct tradeoff between complexity and computational time, which inhibits the inclusion of all regulations related to power generation.

[Line 210] “In addition to these emissions constraints, both scenarios have baseline policies that existed at the end of 2022, including state-level Renewable Portfolio Standards (RPS), the Cross-State Air Pollution Rule (CSAPR), the California Cap and Trade Program...”

I have not worked with this type of open source forecasting model, so I am unable to comment on the specifics.

Revisit the construction of climate engaged states and confirm if using data from Climate X Change’s state policy tracker yields similar twenty-three states. Provide more clarity about your modeling choices and constraints.

Thank you for this suggestion. We addressed this above and were pleased that the CXC approach proved to be consistent with our method.

The manuscript is at times difficult to follow. The authors group most states into regions but separate out California and Texas. This is not intuitive – despite the fact that these states are critically important for climate goals. This approach makes seeing your full results and grasping them more challenging than it should be.

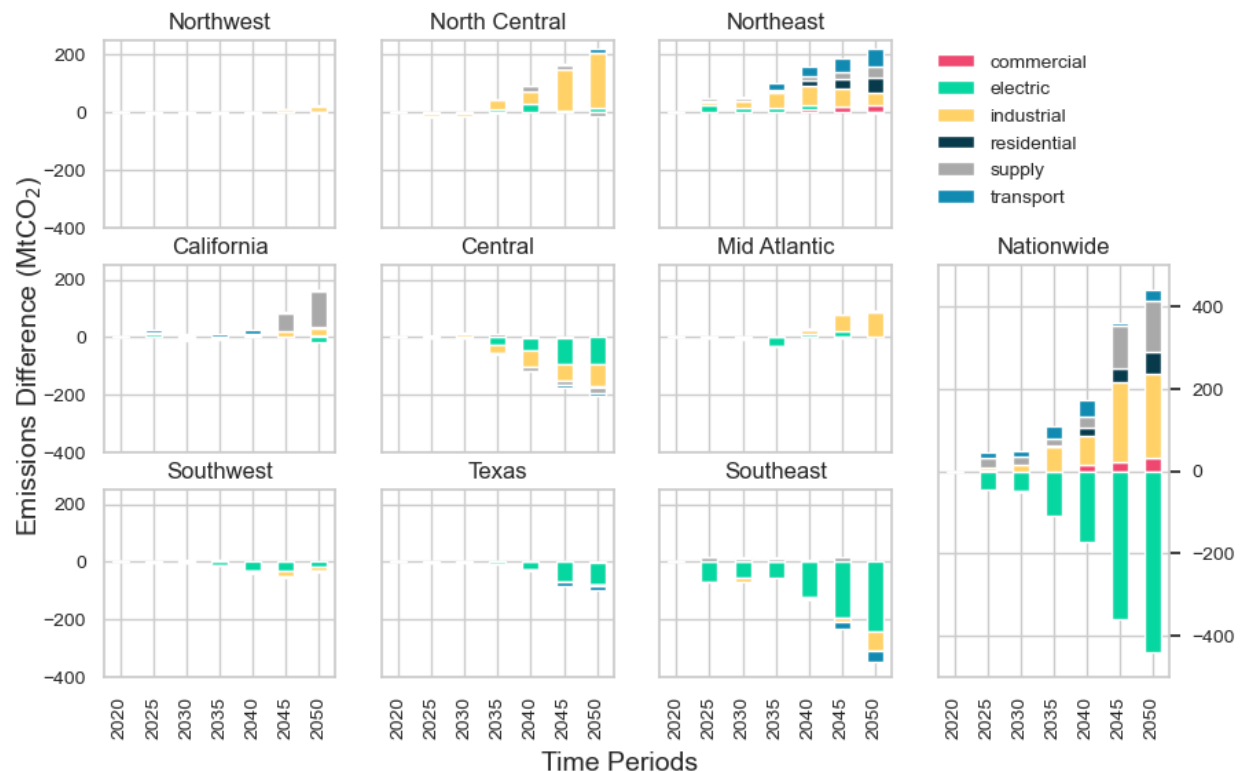
We thank the reviewer for providing insight into where the authors may provide further clarity on modeling choices and have edited the text to improve readability. The regions are selected due to their approximation of existing Regional Transmission Organizations and Independent System Operators and other regional electric balancing authorities. (Note that unlike other states, California and Texas have independent system operators that largely conform to state boundaries.) The motivation for these regions was mentioned within the original manuscript within the Methods Section, now shown in lines 561-562 of the tracked-changes manuscript. However, the authors recognize this information is not immediately intuitive, and not discussed until the end of the manuscript. As a result, additional clarity has been provided in the manuscript.

[Line 619] “Model regions are chosen for their similarity in aggregation to U.S. electric balancing authorities while following state boundaries.”

[Line 202] “Since our approach groups states into regions that largely align with power system balancing authority boundaries, emissions are also aggregated regionally, with reductions proportional to net-zero participation.”

The figures in the paper are difficult to read and the similar color schedule between Figure 2 – which reports emission changes by geography, and the other figures (3, 4&5) report emission changes by sector. Using a different color scheme would help distinguish the figures.

Thank you for this comment. The authors have updated the color scheme for Figure 3 to avoid this confusion.



Reviewer #3 (Remarks to the Author):

The article "Technological Pathways Diverge Under State Versus Federally Led Decarbonization" contrasts two optimization model results to explore the impact of different jurisdictional approaches to climate mandates. The premise is grounded in the United States' federal system, where states have the authority to establish their environmental policies. While the two scenarios do not correspond to actual jurisdictions' policies, the authors pose an intriguing question: what is the difference between addressing climate change at the national level versus placing the burden on the most climate-progressive states? The study reveals distinct mitigation approaches deployed nationally, with minimal cost differences.

We thank the reviewer for recognizing the intrigue of our research question. As mentioned, this exercise is not intended to provide a detailed review of jurisdictional policies, but rather to explore the question of climate governance strategy at a high level using detailed capacity expansion modeling. We believe that

this research question are particularly important given the outcome of the recent U.S. presidential election.

However, the article does not account for the actual variations in state policy portfolios within the U.S., nor do the scenarios align with the federal government's goal of achieving net-zero emissions by 2050.

There are indeed existing state policies that are modeled within both scenarios presented in this manuscript. To provide clarity on this matter for both the reviewers and the manuscript, we made the following changes manuscript:

[Line 210] “In addition to these emissions constraints, both scenarios have baseline policies that existed at the end of 2022, including state-level Renewable Portfolio Standards (RPS), the Cross-State Air Pollution Rule (CSAPR), the California Cap and Trade Program, the federal Investment Tax Credit, and provisions of the Inflation Reduction Act. They are assumed to remain in their current form.”

Despite these limitations, the authors' rationale for conducting this analytical exercise remains valid. The analysis is precise, the results are well-presented, and the evidence supports the article's conclusions. For these reasons alone, the paper should be considered for publication.

We greatly appreciate the author’s recommendation the manuscript be considered for publication.

That said, several recommendations could enhance the article's value, particularly for policy-oriented readers interested in the implications for climate federalism in the U.S. and other federalist systems, such as Brazil or Canada. Additionally, there are a few analytical and discussion-related issues that warrant attention.

1. Federalism and Polycentricity: The authors discuss federalism and polycentricity debates but predominantly focus on federalism throughout the article. The discussion of polycentricity seems misaligned with the paper's objectives, as the concept usually involves a broader range of actors and institutional arrangements than what is considered here (NGOs, cities, academia, etc). The federalism framework alone suffices for this study. Still, the authors could discuss further the nature of US federalism concerning different areas of governance that are relevant to the study.

We thank the reviewer for providing feedback on the authors’ policy framing. This is a valuable correction, which we have completed. This revision includes the removal of polycentricity discussions and further clarity on the federalist policy framing:

[Line 76] “As of late, the answer to this appears to stem from the concept of climate federalism within the policy literature. Climate federalism arose as an academic subject of interest in the United States in the early 21st century. As many recognized the weaknesses of “top-down” approaches (e.g., Kyoto Protocol), there was concurrent recognition of the subnational diffusion of climate governance. In 2023, twenty-four states plus the District of Columbia had specific adopted GHG emission targets.²³ State-level climate and energy legislation has grown over the last decade, and academic interest in

environmental policy at the state level is nearly at a 30-year peak.¹⁸ A rationale for this diffusion of energy and climate policy to subnational groups is that they may use their institutional capacities in more effective ways than the previously postulated “top-down” thinking. Often, to gain a competitive advantage, it is not uncommon for states to take early action.¹⁹ Barry Rabe addressed the benefit states may get from a head-start on climate legislation, quoting a 2007 address to the General Assembly where Pennsylvania Governor Edward Rendell said “I believe renewable energy will dominate the economy of the next two decades...For too long, Pennsylvania has been held back because so much of our employment was in industries that were shrinking. But with renewable energy, we have a chance to be a leader in one of the faster-growing segments of this new economy. We should jump at the chance.”¹⁹ Speaking directly to these trends, Rabe further coined the term “contested federalism,” in which high federal and state involvement may simultaneously occur. The contested element of this behavior arises from the potential conflict of objectives which may occur between the federal and state level, with early examples including the divisive Massachusetts v. EPA 2007 ruling.”

2. 2050 Emissions Benchmark: The article establishes a reference emissions reduction benchmark for 2050, but this benchmark falls significantly short of the national net-zero target. It is roughly half of current emissions, which on a per capita basis would likely still exceed today's global average. This critical detail should be clearly stated in the Abstract and early in the Introduction, as it could significantly alter the study's conclusions if the optimization required achieving more ambitious decarbonization levels.

The authors appreciate the reviewer's desire for transparency when demonstrating model results as it pertains to emissions reductions goals. The abstract has been adjusted to state the following:

[Line 16] “State-led decarbonization results in distinct technology choices, a 0.7% increase in system costs, and nationwide emissions reduction of 46% — substantial, but insufficient for ambitious climate goals.”

Additional text has been included in the Introduction:

[Line 112] “It is important to note that because only a subset of the states would be included as net-zero policy participants, neither scenario would achieve nation-wide net-zero emissions by mid-century. These results, however, will shed light on how a singular goal – namely the reduction of greenhouse gas emissions – could be pursued and achieved (or partially achieved) at different administrative levels, but at different costs and technology choices as driven by local resource availability and other constraints.”

3. State Divisions Based on Political Variables: The authors define state divisions using political variables, referencing one source (Ref 28). It would be beneficial to include references to states with net-zero targets. This would not only aid readers but also justify the methodology of inclusion of states in the "green" category beyond the current net-zero targets.

The authors appreciate this opportunity to strengthen the scenario design rationale. In the revised manuscript, we discuss a second approach to identify net-zero states using the state-level policy tracker Climate X Change, as suggested by another reviewer. The identified net-zero states using our method are

fully consistent with the CXC accounting of states that have at least 16 climate policies. Additionally, the excluded states using our approach fully match the CXC states with 10 or fewer such policies. For more detail, please see our response to Reviewer 1.

[Line 192] “This selection criteria and the resulting net-zero states are consistent with the set of states identified as highly involved in climate legislation in robust state-level policy trackers such as Climate X Change. All selected net-zero states in our analysis have 16 or more climate policies enacted, as identified by Climate X Change, while all other states have 10 or fewer such policies enacted. We acknowledge that there is no single “correct” set of net-zero states, as the enactment of any policy is subject to uncertain passage.”

In addition, we add the following statement that lists states with binding economy-wide net zero targets and notes how all are included in our State Action scenario.

[Line 196] “In addition, the composition of this group of states is likely to change over time in response to evolving political dynamics, shifts in citizen preferences, and the broader policy landscape. We also note that the 23 selected states include all of the states that currently have binding net-zero commitments – California, Colorado, Maryland, Massachusetts, New York, and Rhode Island.”

4. Language and Model Descriptions: The article uses two distinct approaches to discussing findings—one focused on model constraints and results and another that places agency on regions or states by attributing "strategies" or "pursuits" to them. The latter approach is misleading, as it implies that the model's results reflect actual policy decisions, which is not the case. For example, the subtitle "2.4" and sentences like "California and the Northeast rely on different power generation strategies" (line 264) should be revised to avoid this confusion.

The authors appreciate the reviewer’s desire to have accuracy in language when discussing modeling exercises. For the sake of keeping policy narrative intact, the authors believe keeping this language of agency in Sections 3.1 & 3.2 is appropriate. However, adjustments have been made within the Results section, with amendments as follows:

[Line 299] “Low involvement regions select higher emitting technology options when unconstrained in the State Action scenario.”

[Line 319] “Deciphering Strategies: Committed regions select distinct decarbonization paths while integrating DAC and renewables”

[Line 321] “California and the Northeast, which are constrained to a net-zero mid-century goal in the State Action scenario, meet power sector demands through different modeling choices and use carbon management through direct DAC to different ends.”

[Line 341] “In a state-led decarbonization, California’s most cost-effective model selection is to augment renewable electricity through imports from the Southwest, rather than relying on additional in-house generation.”

[Line 391] “High-involvement regions within the state-led scenario select lower-emission fuels than the federally-led scenario.”

5. Conclusion and Policy Implications: The conclusion highlights the relevance of state action in creating a more resilient climate policy system in the U.S., particularly given the uncertainties in national politics. It also touches on issues such as emissions leakage and regional differences in mitigation strategies. The authors should explore the possibility of a third scenario in which distinct state-based systems of climate action cater to regional technological priorities in addition to the national and state-led models discussed.

We thank the reviewer for providing notable expansions of this research question. Further exploration is indeed valuable. However, applying this third scenario is beyond the scope of this paper’s analysis. Additionally, a third scenario would strain the ability to conform to word count and format expectations associated with Nature Communications.

6. Temporal Differences and BECCS: The article focuses on results for the year 2050, but there appear to be significant differences over time that do not simply follow a linear progression. This is particularly evident in Figure 7. Additionally, the prominence of BECCS in the Southeast as early as 2025 is striking and warrants discussion in the context of carbon management strategies.

We appreciate this comment and took several opportunities to draw attention to results that occur before the final time period. To address the reviewer’s support for increased emphasis on early-stage State Action Scenario BECCS deployment, the following language has been added to the tracked-changes manuscript:

[Line 416] “Further striking is this rapid additional deployment in the early model time periods, adding more than its National Action counterpart as early as 2025.”

[Line 523] “Though, it must be mentioned that in the application of technologies such as BECCS in the Southeast, this additional deployment begins as early as 2025. Such a rapid added deployment of technology may have real-world constraints, but its model cost-effectiveness remains.”

[Line 389] “Mitigation in the transportation sector tends to vary more significantly over intervening time periods, partly because the shorter lifetimes of transportation technologies allow for more frequent shifts in technologies or fuels compared to sectors like power generation.”

7. Transmission Capacity and Carbon Leakage: The article provides valuable insights into transmission capacity and carbon leakage. A technical point worth addressing is the exclusion of Canada from the study, given its potential relevance to regional interconnections. This exclusion presents an opportunity to discuss how the issue of carbon leakage might evolve in light of U.S. government plans to enhance regional interconnections.

We thank the reviewer for seeing valuable insights for transmission capacity and carbon leakage discussions. Given the domestic nature of this model, the inclusion of international interconnection is beyond the paper scope. However, the authors agree that additional dialogue on international transmission implications is needed. Provided are added lines discussing this:

[Line 497] “Beyond this, international transmission projects such as the New England Clean Energy Connect (NECEC), connecting Canadian hydropower to the New England region, further alters the dynamic of inter-regional energy accounting. This accounting approach requires further inquiry and suggests the need for careful policy design to avoid adverse outcomes like emissions leakage.”

8. Lastly, the sentence in line 513—“Ultimately, we find moderate emissions reductions from stylized subnational action, unable to meet larger stated federal ambitions”—is somewhat misleading. The method was not designed to match the federal net-zero ambition, so this should not be framed as a finding.

We thank the reviewer for identifying important language clarifications to our conclusions. The sentence has been adjusted to still address the failure of the modeling exercise to meet larger federal goals, but not imply it is a finding.

[Line 584] “This stylized subnational action also fails to meet larger stated federal ambitions. Furthermore, even this reduced mitigation level will be challenging to successfully execute. As a result, we suggest this paper’s National Action scenario be a means to identify where future federal intervention may be most cost-effective and politically resilient. Both scenarios achieved a 45.7% CO₂-eq reduction by 2050 relative to 2020 levels, short of Paris Climate Agreement ambitions.”

Reviewer #4 (Remarks to the Author):

The authors critically relied on the political indicator (0-5) in their analysis to assess the impact of state-level governance on decarbonization projections and the types of technology to deliver them. While some may criticize that the state-level governance structure (or political opportunity for the net-zero outcomes) is too broad a factor that shapes the actual deployment of low-carbon technologies by actors within each state jurisdiction, I believe this approach is still useful in that it well serves the authors’ main objectives to compare the implications of state-led and federal-led decarbonizations.

My main concern, however, pertains to the meaning of their political indicators and their implications for their analysis. I believe the state-level heterogeneity is something that this paper should emphasize and take advantage of rather than downplay. Yet, this paper seems to downplay it for several reasons. First, five elements in their political indicator are highly intercorrelated. This means that there are few states in the middle (say, those that score around 3), and while a large number of states will score either lower than 1 or higher than 4, their heterogeneity may be under-evaluated. Even after assigning scores to each state based on five political indicators, the authors grouped them into nine regions rather than conducting a state-level analysis. This may further mask the state-level differences in both the governance

structure and its decarbonization and the use of technology. Why did the authors conduct the regional analysis rather than the state-level?

The authors appreciate the recognition of study limitations. As mentioned in our response to a previous reviewer, the regions are selected due to their approximation of existing Regional Transmission Organizations and Independent System Operators and other regional electric balancing authorities. As such, the supporting data used in the model is often available only at regional-level resolution. We have updated the text to explicitly state this motivation. Conversion to a state level resolution would require many assumptions and would increase the computational complexity beyond what is realistic for completing scenario runs. As it stands, Temoa runs take anywhere from 24-48 hours. Increasing model resolution, increasing data acquisition at fine resolution, and data downscaling are active areas of research and represent the next frontier for this work.

In addition, we did find a number of states near our cut-off threshold. States just over the threshold included Wisconsin, North Carolina, and New Hampshire, while those under the threshold included Arizona, Kansas, Montana, and Louisiana. These findings highlight that states near the threshold may or may not pursue ambitious climate policies, depending on evolving political, economic, and social dynamics. Our approach captures a spectrum of states, reflecting the diversity in climate policy engagement across the U.S., from those with clear commitments to those where future actions remain uncertain.

Also, the choice of these five elements seems a bit arbitrary. What in the previous literature makes the authors decide on these five elements? Is binary indicator appropriate for Renewable Portfolio / Clean Energy Standard or Greenhouse Gas Reduction Goal? What if a RPS or reduction goal is voluntary as opposed to mandatory? What is the risk of pooling reduction goals of different target years and reduction levels?

We appreciate the reviewer's recognition of the significance of the selected political indicators and their impact on the manuscript's findings. Bromley-Trujillo et al. (2016) provides a robust literature basis validating the use of these indicators. While we could have taken an approach that reflects the relative stringency of RPS policies, we would not expect that to greatly influence the set of states selected for inclusion. This confidence is based, in part, on our response to other reviewers, in which we explored an alternative indicator for identifying states likely to pursue net-zero policies. As noted earlier, the Climate X Change accounting of policies yields a set of states with at least 16 climate policies that are fully aligned with our current approach.

In regards to the RPS policies included, we clarified in the text:

[Line 183] "...the adoption of a state-level Renewable Portfolio Standard/Clean Energy Standard..."

We also note that there is not one "correct" answer for the set of states that should be included in the collection of net-zero states. Over time, the list of plausible states can and will evolve based on changing political representation and citizen preferences. We add the following text to reflect that:

[Line 195] “We acknowledge that there is no single “correct” set of net-zero states, as the enactment of any policy is subject to uncertain passage. In addition, the composition of this group of states is likely to change over time in response to evolving political dynamics, shifts in citizen preferences, and the broader policy landscape.”

After assigning states into nine regions, the authors stated that Temoa model run yielded different decarbonization constraints, ranging from 1.6% to 100%. However, nowhere in the paper or supporting information did the authors explain these steps in detail. How did the model render different levels of decarbonization constraints across nine regions based on the political indicator scores of affiliated states?

The authors appreciate an opportunity to provide further clarity on research question design. We provide an example of methods in the manuscript:

[Line 200] “Initial CO₂-eq emissions rates were then obtained from the Energy Information Administration and used for the 2020 model base year.²⁹ We then assigned unique CO₂-eq emissions constraints to each of the nine Temoa model regions based on the presence of net-zero states and their 2020 baseline emissions. Since our approach groups states into regions that largely align with power system balancing authority boundaries, emissions are also aggregated regionally, with reductions proportional to net-zero participation. For example, North Carolina was the only state in the Southeast region to be classified as a net-zero state in the State Action scenario. As such, Southeastern emissions were constrained to eliminate North Carolina’s share of emissions starting at 2020 levels until reaching net-zero in 2050. This was done for regions with partial net-zero participation.”

In their revised manuscript, I suggest the authors address these issues whenever necessary to better substantiate the political indicator.