

FRONT MATTER**Title**

Modeling Heterogeneous Subnational Climate Action through a Sectoral Tiering Framework: Implications for U.S. Decarbonization Pathways

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Abstract

State governments play a critical role in reducing greenhouse gas emissions to meet the United States’ Paris Agreement targets. However, states vary widely in their capacities and inclinations for enacting climate mitigation policies. Here, we present a sectoral tiering framework to assess state-level mitigation performance across sectors. We implement the tiering system in an integrated assessment model with 50-state resolution of the United States (GCAM-USA) to quantify how heterogeneous ambition shapes national outcomes. We find that in most sectors, states cluster in the lowest-performing tier, which accounts for the majority of sectoral emissions. Enhanced state ambition differentiated by tier can reduce 2035 emissions by 42–51% below 2005 levels, compared with 35% under existing measures. Modest increases in policy adoption and stringency in low-performing states yield larger reductions than comparable increases in high-performing states. These results provide a transparent approach for integrating subnational variation into decarbonization modeling.

Key Policy Insights

- Subnational actors are key to driving greenhouse gas emissions reductions in the United States, particularly in the context of federal policy rollbacks; however, divergence in ambition and implementation across states requires policy-grounded proxies that capture heterogeneity and can be translated into integrated assessment modeling and scenario design.
- Mitigation policy coverage varies across sectors and states; sectors such as industry have few mitigation policies across most states, while the buildings sector shows broader adoption.
- Most of the remaining greenhouse gas emissions that must be mitigated to achieve net-zero are located in states with relatively low historical performance on climate mitigation, highlighting the need to focus mitigation efforts in these states.
- High-ambition action across all states can significantly close the gap, but federal policy remains necessary to achieve the U.S. Nationally Determined Contribution target of a 61–66% reduction in net greenhouse gas emissions by 2035 relative to 2005 levels.

Keywords

Subnational climate action; state heterogeneity; integrated assessment modeling; climate mitigation; climate policy; United States

MAIN TEXT

Introduction

To achieve the Paris Agreement's goal of limiting global warming to well below 2°C above preindustrial levels,¹ countries must intensify their decarbonization efforts.²⁻⁴ While climate mitigation policies are typically discussed in a national context, a growing body of literature has highlighted the need for subnational governments to take a more significant role.⁵⁻⁷ The Intergovernmental Panel on Climate Change (IPCC) has also emphasized the importance of subnational jurisdictions in emissions reductions.⁸ Though a small subset of subnational governments have positioned themselves as leaders in climate action, there are substantial differences in ambition and implementation across subnational jurisdictions.⁹⁻¹¹ The United States, as the second-largest emitter of greenhouse gases and a federal country, is a compelling case study for analyzing the potential for subnational action, particularly given the wide differences in climate ambition across its states and recent federal policy rollbacks.¹²

In 2025, the United States government initiated a second withdrawal from the Paris Agreement, withdrew from the United Nations Framework Convention on Climate Change (UNFCCC), reversed federal climate regulations, and scaled back provisions under the Inflation Reduction Act (IRA) and Infrastructure Investment and Jobs Act (IIJA).¹³⁻²⁰ These measures were expected to substantially advance the U.S. Nationally Determined Contributions (NDC) emissions targets,²¹⁻²³ and their rollback highlights the volatility of federal climate policy and the importance of subnational climate action. Subnational governments in the U.S. have been at the forefront of mitigation efforts by establishing renewable electricity mandates, promoting efficiency and electrification through updated building codes, setting stricter vehicle efficiency standards, among other actions.^{9,24} Even in the context of federal inaction, state governments were able to introduce new climate legislation and policies, as seen in previous presidential terms.^{25,26} Broad coalitions of subnational actors, such as “We Are Still In” and the United States Climate Alliance, formed to advance climate action despite federal rollbacks.^{27,28} However, other states have lagged in adopting and implementing climate policy, resulting in uneven progress across the country.^{10,29,30} This divergence generates heterogeneous mitigation efforts not consistently captured in national-scale modeling.

In order to assess the mitigation potential of subnational climate action, it is essential to take into account these divergent levels of climate ambition at the state level and their implications for aggregate emissions outcomes. The variation in climate action across states, and the factors explaining this variation, have been a focus of existing policy research. Bergquist and Warshaw (2023) sought to quantify these variations in climate ambition across U.S. states by developing an aggregate index of state climate policies from 2000 to 2020, using information on 25 individual energy policies.⁹ Other studies have identified several factors that influence a state's climate policy adoption and stringency, including the power dynamics between public and private interests, political party affiliation at different levels of government, the environmental interest group membership in the state, and the policy diffusion effect across neighboring states.^{10,31-34} Given that there is no single predictor of climate action, it becomes crucial to

develop alternative methods for estimating state ambition through policy-grounded proxies that effectively capture heterogeneity and can be translated into scenario design.

Modeling studies have also addressed the challenge of capturing heterogeneity in state climate policy through various methods. Hultman et al. (2020) divided states into three tiers based on their likelihood of taking accelerated action, considering their historical leadership and willingness to engage in climate mitigation, as measured by variables such as membership in climate organizations and their on-the-books policies.³⁵ Peng et al. (2021) used public opinion on climate action at the state level as a proxy for the heterogeneity in the stringency of state policies and categorized states into three groups, from low- to high-supporting states.³⁶ Mouat et al. (2025) developed a political score that identifies U.S. regions with predicted mid-century net-zero involvement, accounting for the adoption of a state-level Renewable Portfolio Standard/Clean Energy Standard (RPS/CES), a greenhouse gas reduction goal, the political affiliation of the governor and legislative majority, and the presidential vote.³⁷

These studies have advanced the representation of state heterogeneity by integrating political, social, and policy variables, but rely largely on aggregate or indirect indicators of policy intent, limiting their ability to represent how specific policy instruments—with differing ambition levels across sectors and states—translate into emissions outcomes. In practice, state ambition can vary by sector, with stronger policy coverage in some areas than others. For example, Illinois has adopted strong building policies, including compliance with the 2021 International Energy Conservation Code (IECC) and advanced Energy Efficiency Resource Standards (EERS) for electric and gas utilities, but has virtually no measures in the industrial sector.^{38–40} Similarly, Maine has adopted ambitious power-sector policies, including an RPS targeting 80% renewable retail sales by 2030; however, its transportation policies are less ambitious, having failed to pass policies like the Advanced Clean Cars II (ACC II) standards.^{41,42} These variations highlight the need for methods to measure state-level ambition grounded in observed climate policy performance at the sector level.

This study examines variations in state-level climate ambition across sectors in the U.S. and how state-level heterogeneity can influence national emissions outcomes within the current federal climate policy context. This analysis develops a sector-specific state-tiering system and combines this with a scenario-based modeling framework to evaluate state- and sector-level emissions outcomes through 2035 using GCAM-USA, an integrated assessment model that offers full coverage of all emitting sectors across the economy and a detailed representation of all 50 U.S. states and Washington D.C.⁴³ Specifically, the study (1) constructs a sectoral state-tiering framework using a multidimensional index to capture past climate ambition across states and sectors as a proxy for policy heterogeneity; (2) designs a suite of enhanced state ambition scenarios that apply this tiering structure to assess the effects of additional state policy enactment on national emissions trajectories; and (3) compares these scenarios against a baseline existing-measures scenario reflecting current state-level policies.

Methods

Sectoral Tiering and State Tiering Index

In order to model states' potential for climate action, we have further developed the state tiering proxy first introduced by Hultman, Clarke, Frisch et al. (2020).³⁵ As framed in that study, the state tiering proxy divides states into three tiers to allow for more tailored policy assumptions in assessing their economy-wide emission reduction potential. Tier 1 states are the leading states, applying high-ambition and innovative policies to maximize emissions reductions. Tier 2 states are the “followers,” enacting policies similar to Tier 1 states, but with a lagged timeline or a lower level of stringency. Tier 3 states are low-ambition states, expected to enact little to no additional policies in the near-term beyond existing policies due to various political, economic, and institutional constraints.

We introduced two key innovations to this process. First, we developed a systematic and data-driven approach to the allocation of states across tiers by sector, grounded in an index, which we call the State Tiering Index. The previous approach, as outlined by Hultman (2020), classified states into tiers based on expert judgment and a qualitative analysis of the state's membership in climate organizations, vocal leadership in support of climate action, emissions reduction, and on-the-books policies.³⁵ In this study, we formalize that framework by introducing an index to measure historical climate policy performance at the state level. Second, we used this index and applied k-means clustering to categorize states into sectoral tiers based on the similarity of their index values, avoiding the need to manually select thresholds. This approach captures the distribution of state ambition across economic sectors and ensures that tier assignments emerge objectively from the underlying data rather than from predetermined cutoffs or fixed numbers of states per tier.

Indices are a common approach to measuring climate and environmental performance at the national or regional level. They typically incorporate metrics of climate policy, emissions reductions, and other variables.^{11,44,45} The State Tiering Index builds on these methodologies to calculate a weighted score of climate mitigation efforts for each U.S. state across five economic sectors: electricity, transportation, buildings, industry, and land. These sectors follow the same definitions as those used by the U.S. Environmental Protection Agency's (EPA) *2022 Inventory of U.S. Greenhouse Gas Emissions and Sinks*, merging the commercial and residential sectors into a broader buildings sector and including agriculture and LULUCF under lands.⁴⁶

The State Tiering Index is composed of four metrics that capture different dimensions of climate mitigation performance. The first is the State Climate Policy (SCP) score, the primary metric, which reflects the number and stringency of policies enacted in each state and sector. The second, the Emissions Trend (ET) metric, measures realized performance by accounting for observed emissions reductions in that state and sector. The third and fourth are economy-wide adjustments without sectoral variation: the Local Climate Policy (LCP) score and the Climate Commitment (CC) score. These components provide complementary context to the sectoral indicators by recognizing the influence of action at the local level and broader institutional engagement. The aggregation of these four components is expressed in the following equation:

$$(1) \text{ State Tiering Index}_{s,i} = \alpha_1 SCP_{s,i} + \alpha_2 ET_{s,i} + \alpha_3 LCP_s + \alpha_4 CC_s$$

Where:

- $SCP_{s,i}$: State Climate Policy score for state s , sector i
- $ET_{s,i}$: Emissions Trend for state s , sector i
- LCP_s : Local Climate Policy score for state s
- CC_s : Climate Commitment score for state s
- $\alpha_1, \alpha_2, \alpha_3, \alpha_4$: component weights (baseline: $\alpha_1 = 0.6, \alpha_2 = 0.2, \alpha_3 = 0.1, \alpha_4 = 0.1$)

Higher State Tiering Index values indicate stronger historical climate mitigation performance, with scores normalized through Min–Max scaling to ensure comparability across sectors and states. The component weights ($\alpha_1, \alpha_2, \alpha_3, \alpha_4$) were selected to emphasize SCP as the primary metric of climate policy performance, while also incorporating realized performance, as measured by the ET metric; local-level policy performance, as measured by the LCP score; and institutional engagement, as reflected in the CC score. Each index component is detailed in the Supplementary Materials (S1). The proportional structure of the weights ensures that the index reflects both the SCP score and supporting components without over-weighting any single dimension.

As a baseline specification, we set $\alpha_1 = 0.6, \alpha_2 = 0.2, \alpha_3 = 0.1, \alpha_4 = 0.1$. We assign the greatest weight to α_1 (SCP) to ensure that the index is grounded in current state policy action as an indicator of capability and political conditions for future climate action. The next higher weight assigned to α_2 (ET) reflects its role in capturing realized policy performance, whereas the LCP and CC scores serve as economy-wide adjustments that complement, rather than directly represent, sectoral variation. The weighting scheme follows the conceptual role of each component, with sensitivity checks indicating that sector index values and tier assignments are not driven by any single weight choice. These robustness results are detailed in the Supplementary Materials (S1.5, Table S7, Fig. S2).

In addition to the sectoral tiers, we developed an economy-wide tiering to set the modeling assumptions of policies that are not confined to a single sector. The economy-wide tiering is aggregated in the same way as the sectoral tiering, as shown in Equation 1, with two key differences. First, the ET component captures the emissions trend for total net GHG emissions rather than sectoral emissions. Second, the SCP component is calculated as the weighted average of the sectoral SCP scores, where weights correspond to each sector's share of the state's total emissions as of 2022. Through this method, sectors that account for a larger proportion of a state's emissions have a greater influence on the index value than those that are less significant in that state's emissions profile.

The State Tiering Index results were used to classify states into three tiers using k-means clustering. K-means was selected as an unsupervised method to group states based on similarities in their index values across sectors. This approach eliminates the need for predetermined thresholds, establishing tier assignments that reflect the underlying distribution of scores. We decided to use k-means clustering due to its transparency, replicability, and broad

applicability in data analysis.⁴⁷ The number of clusters was set at three, following the Elbow Method for selecting the optimal number of clusters. Conceptually, three clusters also mirror the previous tiering structure presented in Hultman et al. (2020).³⁵ The algorithm was initialized with multiple random starting points, retaining the solution with the lowest within-cluster variance. Diagnostics and validation figures are provided in the Supplementary Materials (S1.3 and Fig. S1).

Scenario Design

In order to evaluate the implications of different levels of state ambition, we designed a suite of State Ambition scenarios as displayed in Table 1. We start with an *Existing Measures* scenario that captures on-the-books policies at the federal and state levels as of September 2025, including federal rollbacks. These policies span all major emitting sectors and include remaining IRA provisions, such as the Production Tax Credit (PTC) for existing nuclear energy and the High-Efficiency Home Rebate Program. At the non-federal level, we modeled current RPS targets, energy efficiency resource standards (EERS), and scheduled retirements of coal-fired capacity, among other policies. The full list, modeling assumptions, and further details can be found in the Supplementary Materials (Supplementary Text S3.1; Table S8).

	Tier 1 States	Tier 2 States	Tier 3 States
Intensified Ambition	Tier 1 ambition	↑ Tier 1 ambition	↑ Tier 2 ambition
Accelerated Ambition	Tier 1 ambition	↑ Tier 1 ambition	Tier 3 ambition
Baseline Ambition	Tier 1 ambition	Tier 2 ambition	Tier 3 ambition
Constrained Ambition	Tier 1 ambition	↓ Tier 3 ambition	Tier 3 ambition
Minimal Ambition	↓ Tier 2 ambition	↓ Tier 3 ambition	Tier 3 ambition
Existing Measures	On-the-books policies		

Table 1. Structure of the State Ambition scenarios (changes relative to *Baseline Ambition*) and the *Existing Measures* scenario. The *Existing Measures* scenario serves as the baseline for all other scenarios and only applies to on-the-books policies without incorporating any tier-based adjustments or additional ambition. The *Baseline Ambition* scenario is the central State Ambition scenario in which each tier retains its reference level of ambition. The arrows indicate when a scenario increases or decreases ambition by one tier relative to *Baseline Ambition*.

We developed a central State Ambition scenario, which we refer to as the *Baseline Ambition* scenario, using the final distribution of tiers as a proxy for differentiated future policy ambition. Under this structure, Tier 1 states are assumed to enact more ambitious policies than other states, Tier 2 states adopt Tier 1–type policies with a delay or lower level of stringency, and Tier 3 states enact few to no additional policies, as described in Table 2. Further details can be found in the Supplementary Materials (Supplementary Text S3.2; Table S9). The *Existing Measures* and the *Baseline Ambition* scenarios are first presented in Zhao et al. (2025).⁴⁸

Sector	Policy	Implementation Assumptions
Electricity	Renewable portfolio standards	T1: 65% by 2035; T2: 50% by 2035; T3: 20% by 2035
	Clean electricity standards	T1: 80% by 2035; T2&3: BAU
	Coal phaseout policies	By phaseout year. T1: 2030 T2: 2035 T3: 2040
Transportation	Light-duty vehicle electrification policies to help achieve targets under Advanced Clean Cars II	By the year of achievement of 100% Electric Vehicle sales. T1: 2038; T2: 2041; T3: 2044
	Medium- and Heavy-duty Vehicle electrification policies to help achieve targets under Advanced Clean Trucks	T1: EV sales equivalent to California's Advanced Clean Trucks targets with a 3-year delay T2&3: BAU
	Vehicle Miles Traveled (VMT) reduction policies	By the percentage of annual VMT per capita reductions by 2035. T1: 1.25%; T2: 0.75%; T3: BAU
	Low-carbon fuel standards	T1: 20% in 2030, 25% in 2035 T2&3: BAU
Buildings	Enhanced energy efficiency resource standards	T1&2: 4% annual efficiency savings by 2030 T3: BAU
	Zero-emission appliance standards	By the year of achieving 100% electric heating and water heating sales. T1: 2035; T2: 2040; T3: BAU
	Zero-emission construction standards	T1&2: 100% new electric construction by 2035. T3: BAU
Industry	Cement Carbon Capture and Storage (CCS) targets	By the percentage of CCS capability in cement production by 2035. T1: 40%; T2: 20%; T3: 10%
Methane	Oil and gas methane regulations	By the cost of reductions or below the EPA's MAC curves ⁴⁹ T1: \$60/tCO _{2e} ; T2: \$30/tCO _{2e} ; T3: \$0/tCO _{2e}
	Landfill waste methane regulations	By the cost of reductions or below the EPA's MAC curves ⁴⁹ T1: \$60/tCO _{2e} ; T2: \$40/tCO _{2e} ; T3: \$20/tCO _{2e}
	Enhanced waste diversion efforts	By the percentage of reduction in landfill waste by 2035. T1: 60%; T2: 40%; T3: 20%
Other	HFC regulations	T1&2: Adopt Significant New Alternatives Policy (SNAP) and Refrigerant Management Programs (RMP) programs T3: BAU

Table 2. Policies modeled under the *Baseline Ambition* scenario.

Implementation assumptions represent increasing levels of ambition across Tier 1 (T1), Tier 2 (T2), and Tier 3 (T3) states. BAU = business as usual (no additional policy).

We also developed four State Ambition scenarios that use the tiering structure to represent upward or downward shifts in state mitigation trends. The *Minimal* and *Constrained Ambition* scenarios reflect reduced policy ambition relative to *Baseline Ambition* while retaining all policies included in *Existing Measures*. In *Constrained Ambition*, Tier 2 states implement additional policies at the Tier 3 level; in *Minimal Ambition*, Tier 1 and Tier 2 states each shift down by one tier. These scenarios represent conditions in which political, institutional, or financial constraints limit additional mitigation policy adoption. Conversely, the *Accelerated* and *Intensified Ambition* scenarios represent higher mitigation pathways. In *Accelerated Ambition*, Tier 2 states adopt Tier 1 policy assumptions; in *Intensified Ambition*, Tier 2 states

adopt Tier 1 assumptions and Tier 3 states adopt Tier 2 assumptions. These scenarios assume that Tier 3 states are unlikely to reach Tier 1 ambition within the modeled timeframe and that Tier 1 states are unlikely to regress to Tier 3 performance. Across the State Ambition scenarios, we model fifteen state-level policies across electricity, transportation, buildings, industry, and methane. Sectoral tiers are applied within each sector, while methane and other cross-sectoral policies use economy-wide tiers. Policy types, stringency levels, and targets are based on the most ambitious existing policies observed within each tier. Full assumptions are provided in the Supplementary Materials (S3, Tables S10–S13).

GCAM-USA

The *Existing Measures* and State Ambition scenarios are modeled using GCAM-USA v8.2, an open-source global Integrated Assessment Model (IAM).⁴³ GCAM-USA is a market equilibrium model that simulates the interactions of energy, land, water, climate, and socioeconomic systems. It has U.S. state-level and sectoral detail, making it particularly well-suited for this analysis. In our study, the model is calibrated to historical data through 2021, and then simulates future outcomes in 5-year time steps from 2025 to 2035. All policies conceptualized in the scenario design were translated into GCAM-USA inputs and applied to the model's baseline to obtain an estimate of the economy-wide implications of these pathways. For additional information on GCAM-USA, see Section S2 in the Supplementary Materials.

Results

State-Level Climate Ambition: Patterns, Constraints, and Validation

The State Tiering Index and resultant tiers reveal large heterogeneity in state climate performance, with distinct patterns emerging across sectors. Figure 1 shows the final State Tiering Index values and distributions of states across all sectoral and economy-wide tiers. The number of states by tier ranges from 6 to 16 states in Tier 1, 11 to 20 in Tier 2, and 23 to 32 in Tier 3, showing that states are skewed toward Tier 3. In each sector, Tier 3 states have few to no mitigation policies in place, reflecting a significant gap in ambition in a substantial number of states. Tier 2 states have several enacted policies, but their scores remain meaningfully lower than those of Tier 1 states, which have multiple policies and moderate-to-high levels of policy stringency. The sector with the most even distribution of states across tiers was the buildings sector, which had an allocation of 14 states in Tier 1, 13 states in Tier 2, and 24 states in Tier 3. This comparatively even distribution is due in part to the broad adoption of energy efficiency standards and incentives across most states, reflecting bipartisan support for energy efficiency.⁵⁰ In contrast, the industry sector had only 7 states reaching the Tier 1 classification, while 32 fell into Tier 3, as most states have no policies to mitigate industrial emissions due to the technical and political challenges associated with decarbonizing this sector.^{51,52}

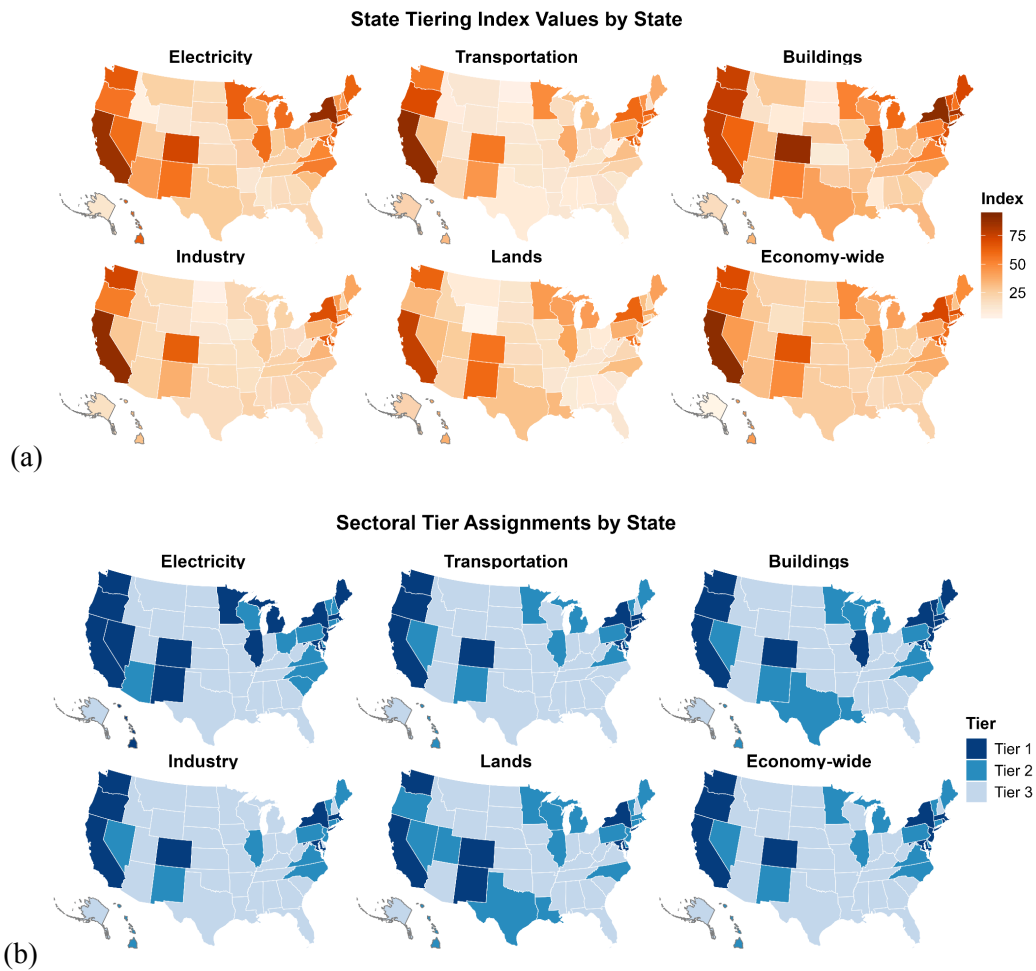


Fig. 1. State Tiering Index Values and Sectoral Tier Assignments by State

a. State Tiering Index values across sectors and for the economy-wide score. **b.** Sectoral tier classifications derived from the clustering of the index values. Tier 1 indicates the strongest historical climate policy performance, Tier 2 reflects moderate performance, and Tier 3 reflects limited performance.

Several top-performing and low-performing states kept a consistent tier assignment across all sectors. States such as California, New York, and Washington remained in Tier 1 across all sectors; Pennsylvania remained in Tier 2, and Idaho, Wyoming, and Kansas remained in Tier 3. Most of the variation in classification came from mid-performing states, whose tiers vary by sector. For instance, Connecticut exhibits Tier-1 performance in the buildings and transportation sectors, but Tier-2 in the electricity and industry sectors. These results reflect the state's meaningful action in the transportation and buildings sectors, including building energy codes that align with the 2021 IECC, an ambitious EV rebates program, and a target of 5% reduction in VMT per person by 2030.^{53–55} However, it has virtually no industry policies, and its electricity policies are less stringent than other states, as evidenced by its moderate RPS and energy storage targets. The State Tiering Index proves particularly useful in instances where mitigation performance varies meaningfully across sectors within a state.

Figure 2 illustrates the distribution of GHG emissions across sectoral tiers, showing their potential for absolute reductions. Given the skewness of the classification towards Tier 3, most emissions are concentrated in that tier. The only exception is the buildings sector, where Tier 1 states account for a larger share of emissions than Tier 2 and Tier 3 states. This distribution highlights a significant constraint: most emissions originate in Tier 3 states, which are also the weakest in climate mitigation performance as measured by the index. The low likelihood of deep decarbonization in these states limits the potential for emissions reductions under current trends, absent federal climate leadership. Historical emissions trajectories aggregated by tier (Fig. S3, Supplementary Materials) also show that Tier 3 states have consistently accounted for the largest share of net GHG emissions over time. In this context, it becomes particularly important to explore the outcomes of mitigation strategies that vary at different levels of ambition across states and sectors, which the State Ambition scenarios were structured to evaluate.

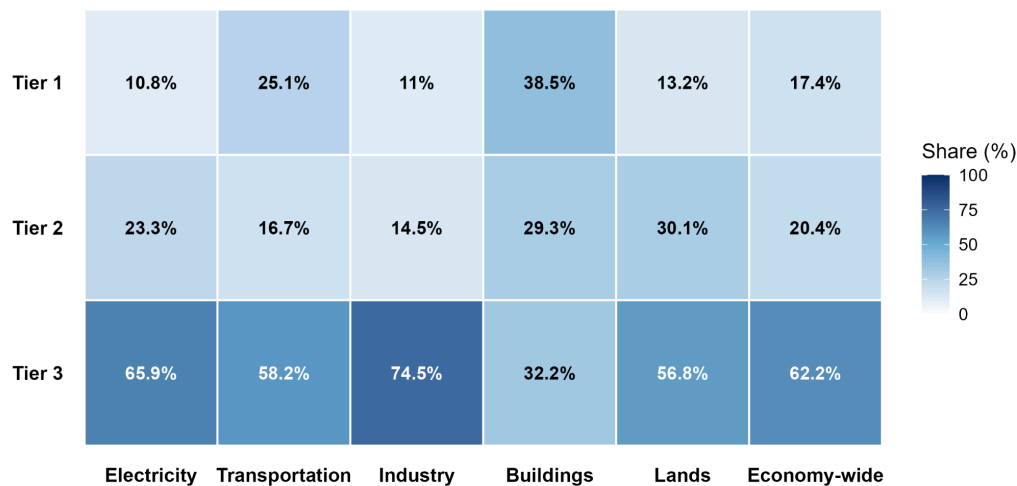


Fig. 2. Share of Aggregate Sectoral GHG Emissions from States in Each Tier

Sectoral emissions totals correspond to the year 2022 and were obtained from the U.S. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022*.⁴⁶

Additionally, we compared the State Tiering Index economy-wide results with other metrics used in modeling studies to capture state heterogeneity, such as public support for climate mitigation—as measured in the 2018 Yale Climate Opinion Map (YCOM)—used by Peng et al. (2021), and the political score developed by Mouat et al. (2025).^{36,37,56} We also compare it with the state climate policy index developed by Bergquist and Warshaw (2023), which is conceptually the closest to our State Tiering index, as it measures climate policy performance at the state level using information from 25 individual policies.⁹ All of these other metrics are at the state level but not the sector level, so we only compare them against the State Tiering Index economy-wide results for better correspondence.

As shown in Figure 3, the State Tiering Index has a strong positive monotonic relationship with the climate policy index by Bergquist and Warshaw (2023). The State Tiering Index also shows a strong positive correlation with the political score developed by Mouat et al. (2025), although the greater dispersion among states with the highest political scores indicates that, even among

states with strong pro-climate political alignment, there can be differentiated mitigation performance levels. The relationship with the percentage of adults supporting more local climate action, as a proxy for political willingness, is significant but weaker, as expected, given that public opinion is an indirect indicator of political willingness and is less tightly linked to enacted climate policy than the other two measures. Spearman correlations confirm these relationships ($\rho = 0.88$ for Bergquist; $\rho = 0.88$ for Mouat; $\rho = 0.56$ for YCOM; all $p < 0.001$). These strong correlations show that the State Tiering Index captures meaningful differences in policy strength and political context, which align and build on the proxies employed in previous studies.

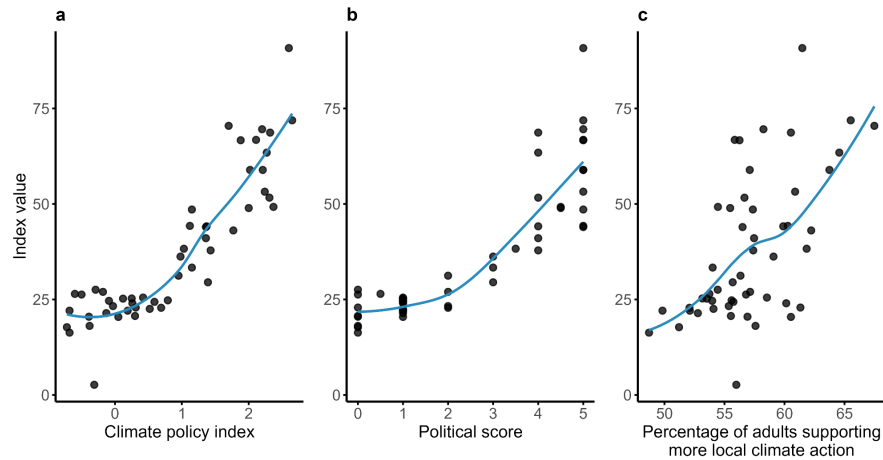


Fig. 3. Relationship between the economy-wide State Tiering Index results and other state-level indicators of climate performance and propensity for mitigation.

a, Association between the State Tiering Index economy-wide score and the state climate policy index in 2020, developed by Bergquist and Warshaw (2023).⁹ **b**, Association between the State Tiering Index and the political score developed by Mouat et al. (2025).³⁷ **c**, Association between the State Tiering Index and the percentage of adults who believe their local officials should do more to address global warming, based on the 2018 Yale Climate Opinion Map (YCOM), as used in Peng et al. (2021).³⁶ Each panel shows individual state values and a Locally Estimated Scatterplot Smoothing (LOESS) curve.

National Emissions Outcomes Under Varying State Ambition Levels

The *Baseline Ambition* scenario, the central pathway in which each state enacts policies consistent with its past mitigation performance as classified by the tiering system, achieves a 46% reduction below 2005 levels by 2035 (3,558 MMtCO₂e), compared to a 35% reduction (4,231 MMtCO₂e) under *Existing Measures*. Across the State Ambition scenarios, reductions range from 42% to 51% below 2005 levels by 2035 (3,783 to 3,195 MMtCO₂e). Annual decarbonization rates accelerate from 1.7% under *Existing Measures* (81 MMtCO₂e/year between 2021 and 2035) to 2.5-3.6% across the State Ambition scenarios (113-155 MMtCO₂e/year).

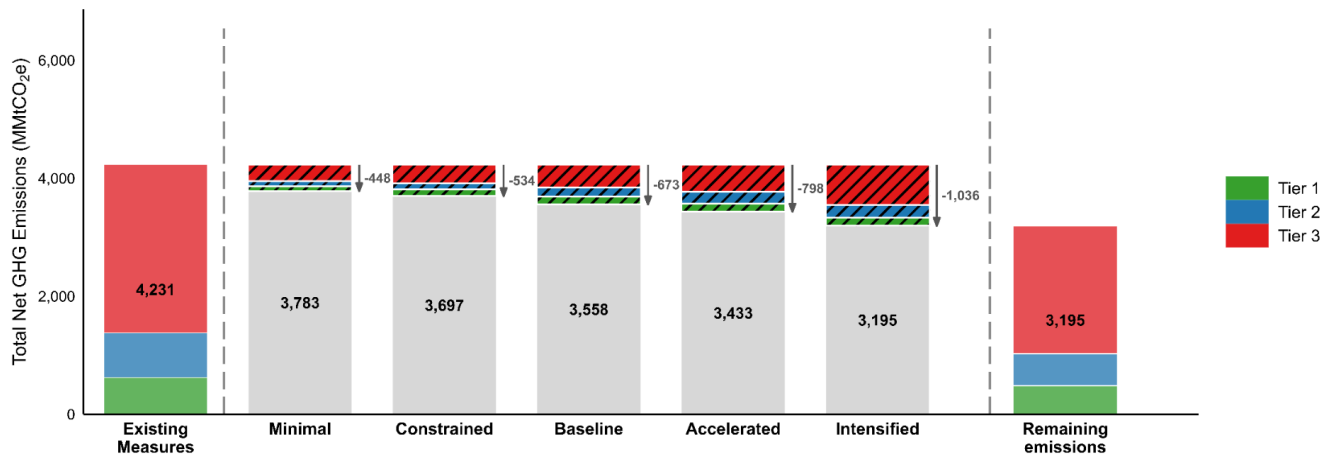


Fig. 4. U.S. net GHG emissions in 2035 under State Ambition scenarios, with tier-specific reductions relative to Existing Measures.

Bars show total modeled U.S. net GHG emissions in 2035 (MMtCO_{2e}) under *Existing Measures* and the State Ambition scenarios (*Minimal*, *Constrained*, *Baseline*, *Accelerated*, *Intensified*, see Table 1). The solid gray portion represents remaining emissions under each State Ambition scenario, while the striped colored segments show reductions relative to *Existing Measures*, disaggregated by tier. The final bar shows remaining emissions under the *Intensified Ambition* scenario, divided by tier. Bold numbers indicate remaining emissions in each scenario.

The largest stepwise reductions occur when new policy ambition is introduced in Tier 3 states (Figure 4). The shift from *Existing Measures* to *Minimal Ambition* yields an additional 448 MMtCO_{2e}, driven by a 20% RPS, vehicle electrification, and limited cement CCS, while the shift from *Accelerated* to *Intensified Ambition* yields an additional 238 MMtCO_{2e}, concentrated in the power sector. Other tier shifts produce smaller incremental reductions of 86–139 MMtCO_{2e}, with gains distributed across transportation, buildings, and the power sector. This pattern reflects the concentration of current emissions in Tier 3 states and indicates that expanding and strengthening mitigation policies in low-performing states can yield larger national reductions than increasing stringency in already high-performing ones.

Sectoral Transformations Under State Ambition Scenarios

To achieve the aforementioned national outcomes, the State Ambition scenarios involve multiple transformations across sectors, with the magnitude and timing of change varying by tier (Fig. 5). In the electricity sector, all tiers increase clean and renewable shares under both the *Baseline Ambition* and *Existing Measures* scenarios, with the largest marginal gains under *Baseline Ambition* concentrated in Tier 2 states, which rise from 39% clean electricity in 2021 to 70% by 2035 (versus 59% under *Existing Measures*). Tier 1 states reach 83% under *Baseline Ambition* (versus 78% under *Existing Measures*), and Tier 3 states rise from 31% to 57% (versus 52%). Strengthened RPS, CES, and accelerated coal phaseout drive these transitions. Tier 3

states retain an overall higher renewable share than Tier 2, reflecting the already high penetration of wind and solar in states such as South Dakota, Texas, Iowa, and Kansas.

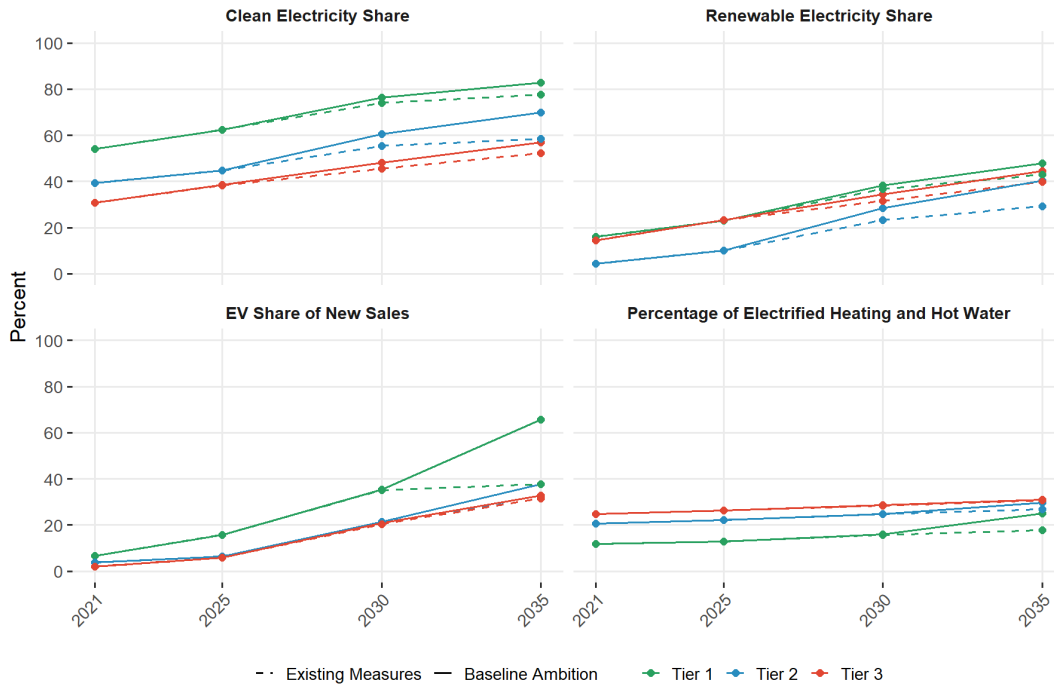


Fig. 5. Key clean energy and electrification metrics in the *Existing Measures* and *Baseline Ambition* scenarios in 2035.

In transportation, *Baseline Ambition* achieves higher EV adoption across all tiers compared with *Existing Measures*. Tier 1 states show the strongest acceleration, reaching 66% of new light-duty sales by 2035 (versus 38% under *Existing Measures*), Tier 2 rises modestly to 38% (versus 32%) and Tier 3 states only marginally to 33% (versus 32%), reflecting the differentiated electrification timelines in Table 2. Buildings transform more slowly across all tiers due to existing stock turnover. Under *Baseline Ambition*, Tier 1 shows the largest electrification gains, rising to 25% (versus 18%), and Tier 2 rises to 30% (versus 27%). Tier 3 states begin with a relatively high baseline—driven by warm-climate states with less heating demand like Florida and Texas—but show smaller gains. Together, these patterns show that differentiated ambition can narrow gaps in some sectors and widen them in others, better reflecting historical trends than assumptions of uniform action.

Discussion

As state governments take center stage amid federal climate policy rollbacks, it becomes increasingly important to evaluate the potential, limitations, and implications of enhanced subnational action. In that process, state heterogeneity is a key component to consider, as it can be both a source of policy experimentation and diffusion and a feasibility constraint that limits the ability to achieve national decarbonization targets.^{57,58} Clustering states by mitigation performance with sector-level detail enables modeling assumptions tailored to each group's

political and institutional realities. It also supports the design of scenarios that display a range of climate mitigation levels, including departures from past trends, through systematic variation in tiers' ambition levels, as showcased in our analysis.

Aside from being a useful proxy for modeling subnational action, the sectoral tiering framework offers meaningful insights on its own. Across almost all sectors, most states fall into the low-performing cluster (Fig. 1), revealing an uneven distribution of mitigation efforts across the country. The framework also supports identifying sectors with gaps and areas of progress in mitigation, such as the industry sector, where most states have few to no climate policies, and the buildings sector, where nearly all states have enacted regulations of at least moderate stringency. The State Tiering Index, as a metric of performance, also shows strong correlations with independent indicators of policy strength and political conditions, suggesting underlying relationships that merit further study.

Leveraging the sectoral tiering framework to model State Ambition scenarios revealed differentiated impacts across varying levels of ambition in national decarbonization pathways. Each shift in ambition across tiers led to increases in emissions reductions. Even the scenario with the lowest level of additional ambition led to additional reductions of 448 MMtCO₂e relative to the existing measures baseline. The modeling of additional policies in Tier 3 states proved to have a major effect on the national outcomes, given that most of the remaining emissions come from low-performing states. This differentiated impact was also evidenced by other metrics, such as the shares of clean and renewable energy. These findings highlight the potential of decarbonization in low-performing states, where policy adoption has lagged.

Despite the decarbonization reflected in the State Ambition scenarios, none of the national emissions outcomes considered here meet the U.S. Nationally Determined Contribution (NDC) target set by the United States in 2024 to achieve reductions of 61% to 66% in emissions by 2035 relative to 2005 levels.⁵⁹ There remains a gap of 656 MMtCO₂e to reach the lower boundary of the target in the most ambitious *Intensified Ambition* scenario. Although a scenario in which Tier 3 states adopt Tier-1 stringency levels would further narrow this gap, such a transition would require political, institutional, and administrative changes that are unlikely to occur within a single decade as modeled here. Under these circumstances, achieving the 2035 NDC target would require all states to raise their policy ambition to the highest levels, exceeding their historical mitigation performance.

In this study, the sectoral tiering framework is used as a proxy for heterogeneity in a modeling application by clustering states by similar historical mitigation policy performance to structure scenario assumptions. Consequently, the index should not be interpreted as a comprehensive scorecard of state performance, as it includes a finite set of historical indicators that do not capture policy enforcement, which can meaningfully impact emissions outcomes.⁶⁰⁻⁶² Although sensitivity tests show tier assignments are generally robust (see Supplementary Materials S1.5), the final distribution also depends on the chosen weighting scheme and clustering method, and states near tier boundaries may be reclassified under alternative specifications or classification approaches (e.g., hierarchical clustering, quantile classification).

Conclusion

As countries continue to develop decarbonization pathways to meet the Paris Agreement, it is crucial to account for subnational variation. This study presents a structured framework that captures state-level heterogeneity in a transparent and systematic way, improving the realism and interpretability of bottom-up modeling. By applying the sectoral tiering framework in GCAM-USA, we show how differentiated state ambition across sectors can shape national decarbonization outcomes through 2035. The same framework can be adapted to other regional contexts with heterogeneous subnational actors, supporting the identification of areas with high potential for emissions reductions and structural challenges to decarbonization.

In the United States context, the results indicate that enhanced state ambition differentiated by tier can reduce 2035 emissions substantially below existing-measures outcomes, but still leaves a gap to meeting the 2024 NDC targets. Across scenarios, modest increases in policy adoption and stringency in low-performing states yield larger marginal reductions than increases in already high-performing states, underscoring the importance of targeting policy expansion where historical policy coverage and implementation have lagged.

Future work could extend the study's approach by analyzing a broader set of political and institutional indicators and their relationships to mitigation performance as measured by the index, modeling sector-specific decarbonization strategies using the tiering system, and exploring scenarios in which federal policies are introduced under subsequent administrations. In parallel, applying this framework to other countries with multi-level governance could support more comparable cross-regional assessments of decarbonization potential and constraints.

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Author contributions:

KOO, AZ, and RC conceived and designed the study. Methodology was developed by KOO, AZ, KTVO, MB, SJS, RC, and KMK. Data collection was conducted by KOO, CVS, and SV. Modeling and analysis were carried out by KOO, AZ, KTVO, and AB. Visualization was prepared by KOO. The study was supervised by RC, SJS, and NH. KOO drafted the manuscript. All authors (KOO, AZ, KTVO, MB, SJS, KMK, RC, CVS, SV, AB, and NH) contributed to revising the manuscript.

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Upon publication, the data that support the findings of this study will be openly available in Figshare at <https://doi.org/10.6084/m9.figshare.31901953>. Before publication, it can be accessed at <https://figshare.com/s/a05498ca78c5d2a3cf2b>

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Supplementary Materials for
**Modeling Heterogeneous Subnational Climate Action through a Sectoral
Tiering Framework: Implications for U.S. Decarbonization Pathways**

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S1. Sectoral Tiering Framework

The State Tiering Index comprises four metrics that capture different dimensions of climate mitigation performance. The first is the State Climate Policy (SCP) score, the primary metric, which reflects the number and stringency of policies enacted in each state and sector. The second, the Emissions Trend (ET) metric, measures realized performance by accounting for observed emissions reductions in that state and sector. The third and fourth are economy-wide adjustments without sectoral variation: the Local Climate Policy (LCP) and Climate Commitment (CC) scores. These components provide complementary context for the sectoral indicators by recognizing the influence of local-level action and broader institutional engagement. We aggregate these components as follows:

$$(1) \text{ State Tiering Index}_{s,i} = 0.6 \times SCP_{s,i} + 0.2 \times ET_{s,i} + 0.1 \times LCP_s + 0.1 \times CC_s$$

Where $SCP_{s,i}$ denotes the State Climate Policy score for state s in sector i , $ET_{s,i}$ denotes the Emissions Trend metric for state s in sector i , and LCP_s and CC_s denote the economy-wide Local Climate Policy and Climate Commitment scores for state s , respectively.

Higher State Tiering Index values indicate stronger historical climate mitigation policy support, with scores normalized through Min–Max scaling to ensure comparability across sectors and states. All State Tiering Index values are reported on a 0 to 100 scale for ease of interpretation in Table S1. The State Tiering Index results were finally used to classify states into three tiers using k-means clustering. The following sections describe each component and its calculation and report the resulting tier assignments.

S1.1 Construction of the State Climate Policy (SCP) Metric

The State Climate Policy (SCP) score assesses a state's enacted policies, considering the stringency level of each policy. It is calculated as the sum of sectoral policies enacted by a state, weighted by a stringency scale (1 = low, 2 = moderate, 3 = high). The equation of the SCP metric is structured as follows:

$$(2) \quad SCP_{s,i} = \sum_{p=1}^{n_i} P_{s,p} S_p$$

Where the $SCP_{s,i}$ metric for state s and sector i is calculated as the sum of all policies p enacted in that sector. Each policy is represented by a binary variable of presence ($P_{s,p}$, equal to 1 if

enacted and 0 otherwise) multiplied by its stringency level (S_p , scored from 1 to 3, where 1 is least stringent and 3 is most stringent).

The SCP dataset includes 66 state-level mitigation policies across five sectors: electricity, transportation, buildings, industry, and land, with the number of policies per sector ranging from 11 to 17. The policies and relevant information were sourced primarily from ClimateXChange's *State Climate Policy Dashboard* and supplemented with additional data collection in the industry, transportation, and land-use sectors. Sector-specific policy lists, scoring thresholds, and data sources are detailed in Sections 1.1.1 through 1.1.5 below.

Stringency scoring follows the same process for all sectors. When a policy has a comparable quantitative ambition parameter (e.g., targets, timelines, thresholds, funding levels, or coverage), we define low/moderate/high cutoffs based on the distribution of observed policies across states, and assign a score of 3 to the most ambitious observed values. When there is no standardized quantitative benchmark, we score based on the presence of policy. Under this presence-based evaluation, policies that are rare but unambiguously signal high ambition are scored at the highest stringency level (3), and all others, where there is greater ambiguity or frequency across states, are scored at 1.

S1.1.1 Electricity Sector

For the full list of policies and stringency ranges in the electricity sector, please refer to Table S2. We use quantitative thresholds where policies have comparable targets, and presence-based scoring otherwise. For policies with measurable targets, such as RPS goals and coal phaseout years, we used the distribution of existing targets to define ambition thresholds. States with a near-term RPS of 60 percent or more by 2030–2035 received a score of 3, while moderate and lower targets were scored accordingly. Coal phaseout policies were scored based on the earliest committed retirement year, with a score of 3 given to states targeting 2030 or earlier. We separated near-term and long-term RPS targets, scoring each independently to reflect their differentiated policy signals. For 100 percent clean electricity goals, we assigned a score of 3, consistent with the presence-based evaluation for rare but high-ambition policies. For the remaining policies in this sector, which do not fit standardized thresholds, we scored based on policy presence. Interconnection standards were scored using the Freeing the Grid letter grade: A or B received a 3, C a 2, and D or lower a 1.¹

S1.1.2 Transportation Sector

Consistent with the SCP scoring approach described above, we used quantitative thresholds where a comparable measurable parameter exists (e.g., rebate levels) and used presence-based scoring where it does not. For the full list of policies and stringency ranges, please refer to Table S3. To score the ambition of EV rebates, we examined the distribution of existing policies and identified three main funding ranges, which served as the cutoffs for ambition levels. For MHDV vehicle transition and VMT reduction policies, which do not have standardized quantitative benchmarks and remain rare, we assigned a score of 3 to states that have promulgated such policies in these categories. We also gave states that adopted California’s Advanced Clean Cars II a score of 3, given the rapid transition to EV sales required by that policy. We assigned lower ambition scores to states with EV policies lagging behind California’s timeline. We gave a maximum ambition score of one for policies such as (EV) charging infrastructure plans and transportation greenhouse gas emissions reduction targets, given that they are non-binding.

S1.1.3 Buildings Sector

In the buildings sector, we apply the same scoring process, using thresholds informed by the distribution of benchmarks where comparable quantitative ambition parameters exist and presence-based scoring otherwise. For the full list of policies and stringency ranges, please refer to Table S4. Building codes, adopted for both residential and commercial buildings in most states, are updated every three years by the IECC. As a result, we gave states scores for this sector based upon the recency of the standard used in each state, giving a score of three to those that have updated their standards to at least the 2021 regulations. Building Performance Standards and Clean Heat Standards are scored using the presence-based criteria. Given that only a handful of states have enacted these standards and that they are highly ambitious, states with these policies receive a score of 3. We based our EERS ambition scores on existing analysis of EERS stringency, holding electricity plans to a higher standard than gas.² To determine weatherization funding ambition, we used the State Policy Opportunity Tracker (SPOT), which “breaks clean energy policies down into ‘components’, which are binary questions to evaluate policy quality,” noting that “higher quality policies have more of their SPOT components fulfilled.”³ Building electrification is important to building decarbonization, but policies rarely

mandate full electrification, so we apply the presence-based high-ambition rule and assign a score of 3 to states with an all-electric buildings policy.

S1.1.4 Industry Sector

Given that most industrial policies lack standardized quantitative ambition parameters comparable across states and that policy uptake is limited in this sector, we apply presence-based scoring following the stringency scoring process. For the full list of policies and stringency ranges, please refer to Table S5. Enacted industrial policies are assigned the highest stringency score of 3 due to their limited presence across states. These include Buy Clean programs, decarbonization grants, emissions standards, and methane and HFC regulations.

S1.1.5 Lands Sector

We use policy presence for most land policies, since comparable quantitative benchmarks are often not available across states. For the full list of policies and stringency ranges, please refer to Table S6. Given lower policy uptake across states, as well as varied circumstances, ecosystems, agricultural industries, and potential conservation areas by state, which make interstate comparisons difficult, we used the binary presence-based scoring for most metrics in this sector. A few exceptions exist, including policies on sectoral planning, smart growth, conservation targets, conservation funding, and all methane programs. Where policies support additional differentiation (e.g., conservation targets), states received up to a three for that policy, depending on its robustness.

S1.2 Emissions Trend (ET), Local Climate Policy (LCP), and Climate Commitment (CC) Formulas and Sources

In addition to the SCP score, three complementary metrics were developed to capture distinct aspects of ambition—realized performance (ET), local-level action (LCP), and institutional commitment (CC)—allowing the index to integrate policy design, performance, and implementation context. As before, all metrics are normalized to fall between 0 and 1 using Min–Max scaling. The ET, LCP, and CC metrics are calculated from different data sources and at different levels. The ET metric is calculated at the sector level, while the LCP and CC metrics are economy-wide adjustments applied uniformly across sectors for a given state.

S1.2.1 Emissions Trend (ET) Metric

The ET metric captures realized emissions performance by measuring the average yearly rate of change in net greenhouse gas (GHG) emissions from 2005 to 2022 for each state and sector. Emissions data were obtained from the U.S. Environmental Protection Agency Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022.⁴ The baseline year, 2005, was selected because many U.S. states achieved substantial emissions reductions after that year, and a later baseline would not capture those earlier reductions.

The ET was calculated through the following equation:

$$ET_{s,i} = \frac{1}{T} \sum_{t=2006}^{2022} \left(\frac{E_{s,i,t} - E_{s,i,t-1}}{E_{s,i,t-1}} \right)$$

Where $E_{s,i,t}$ is net GHG emissions in state s , sector i , and year t from 2005 to 2022. Negative values indicate annual declines in emissions.

S1.2.2 Local Climate Policy (LCP) Metric

The Local Climate Policy (LCP) score takes into account local mitigation actions, highlighting how incorporated places contribute to the state's overall ambition. It assesses the incorporated places that comprise a significant share of the state's CO₂ emissions and are adopting ambitious climate measures, highlighting states where local-level action plays a major role. To calculate the LCP score, we first identified incorporated places that account for more than 2.5 percent of a state's CO₂ emissions, using the Vulcan v4.0 dataset.⁵ This cutoff restricts the incorporated place list to a manageable number of cities for manual verification and scoring, while ensuring that the LCP metric is driven by places that contribute a non-trivial share of state emissions. The threshold yields 157 incorporated places and includes at least one incorporated place in each state, with three exceptions: Washington, DC (a city-level jurisdiction), Wyoming (mostly composed of small towns and municipalities), and Hawaii (as the only state with no incorporated places). The full list of incorporated places is provided in the repository for transparency and reproducibility.⁶

For each incorporated place j , we scored the presence of six equally weighted policies: (1) a climate action plan, (2) at least one sustainable transportation policy, (3) building codes or policies that are stricter than the state's building code, (4) at least one sustainable procurement policy, (5) a clean energy target, and (6) a waste reduction goal. Each incorporated place receives one point per policy enacted, resulting in a place-level score that ranges from 0 to 6:

$$Score_j = \sum_{k=1}^6 I_{j,k}$$

Where $I_{j,k}$ equals 1 if policy k is present in place j , and 0 otherwise.

To aggregate to the state level, we weighted each incorporated place by its share of the state's CO₂ emissions and summed across all eligible incorporated places:

$$LCP_s = \sum_{j \in J_s} (Share\ of\ CO2_{j,s} \times Score_j)$$

Where $Share\ of\ CO2_{j,s}$ is the incorporated place's share of state CO₂ emissions, and J_s is the set of incorporated places in state s exceeding the 2.5 percent threshold. This construction allows local climate action to contribute proportionally to the state's overall ambition score, while limiting the influence of small jurisdictions with negligible emissions shares.

S1.2.3 Climate Commitment (CC)

The CC score captures the broader institutional environment that enables or constrains policy ambition, independently of sectoral policy adoption. The CC score is based on three components that are designed to contribute equally: (1) the presence of a state-level economy-wide GHG reduction target, (2) the presence of climate-focused offices and staff (climate governing bodies), and (3) membership in climate coalitions.

The first two components are coded as binary indicators using ClimateXChange State Climate Policy Dashboard data.⁷ Coalition membership is measured as an aggregated participation metric across the following coalitions and initiatives: U.S. Climate Alliance, Under2 Coalition, Powering Past Coal Alliance, the Medium- and Heavy-Duty (MHD) ZEV Deployment Support MOU, the State Buy Clean Partnership, and the State Modern Grid Deployment Initiative.⁸⁻¹³ These coalitions were selected to represent a diverse set of alliances and initiatives, with a minimum of ten member states and varying sectoral or cross-sectoral focuses.

Each coalition membership contributes one point to the participation score, except for membership in the U.S. Climate Alliance, which contributes two points due to its economy-wide

relevance and high levels of policy engagement. We normalized the coalition participation aggregate value so that this component ranges from 0 to 1. We then calculate the CC score as the sum of the presence of a state-level economy-wide GHG reduction target, the presence of climate-focused offices and staff, and the normalized coalition participation score, yielding a value between 0 and 3.

S1.3 K-means clustering application

We assigned states to tiers using k-means clustering applied to the State Tiering Index values, separately for each sector and for the economy-wide index. K-means was selected as an unsupervised and transparent method that partitions states into groups based on similarity in index values, without relying on predetermined thresholds. It was run in R (version 4.3.2) using the base `kmeans()` function with Euclidean distance and three clusters. We repeated k-means across 1000 random seeds to reduce dependence on starting centroids, and the clustering solution with the lowest within-cluster sum of squares was retained. Cluster centers were ordered from highest to lowest mean index value and labeled Tier 1, Tier 2, and Tier 3. The code used to compute index values, run clustering, and generate the figures is included in the project repository.⁶

We set the number of clusters to three using the elbow method, which indicates diminishing marginal improvement in within-cluster fit beyond three clusters. (Fig. S1) The three-tier structure also mirrors the tiering approach in Hultman et al. (2020), improving interpretability and consistency with prior modeling studies while allowing the tier boundaries to be determined by the empirical distribution of index scores rather than by manual cutoffs.¹⁴

S1.4 Final tier assignments

The complete lists of states categorized into Tier 1, Tier 2, and Tier 3 by sector are listed below.

Electricity Sector

- **Tier 1 states:** California, Colorado, the District of Columbia, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, Minnesota, Nevada, New Jersey, New Mexico, New York, Oregon, and Washington
- **Tier 2 states:** Arizona, Connecticut, Delaware, New Hampshire, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Vermont, Virginia, Wisconsin

- **Tier 3 states:** Alabama, Alaska, Arkansas, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Montana, Nebraska, North Dakota, Oklahoma, South Dakota, Tennessee, Texas, Utah, West Virginia, and Wyoming

Buildings Sector

- **Tier 1 states:** California, Colorado, Connecticut, the District of Columbia, Illinois, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, Vermont, and Washington
- **Tier 2 states:** Delaware, Hawaii, Louisiana, Michigan, Minnesota, Nevada, New Hampshire, New Mexico, North Carolina, Pennsylvania, Texas, Virginia, Wisconsin
- **Tier 3 states:** Alabama, Alaska, Arizona, Arkansas, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Kentucky, Mississippi, Missouri, Montana, Nebraska, North Dakota, Ohio, Oklahoma, South Carolina, South Dakota, Tennessee, Utah, West Virginia, and Wyoming

Transportation Sector

- **Tier 1 states:** California, Colorado, Connecticut, the District of Columbia, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Washington
- **Tier 2 states:** Delaware, Hawaii, Illinois, Maine, Michigan, Minnesota, Nevada, New Mexico, Pennsylvania, Vermont, and Virginia
- **Tier 3 states:** Alabama, Alaska, Arizona, Arkansas, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Montana, Nebraska, New Hampshire, North Carolina, North Dakota, Ohio, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, Utah, West Virginia, Wisconsin, and Wyoming

Industry Sector

- **Tier 1 states:** California, Colorado, Maryland, Massachusetts, New York, Oregon, Washington
- **Tier 2 states:** Connecticut, Hawaii, Illinois, Maine, Nevada, New Jersey, New Mexico, North Carolina, Pennsylvania, Rhode Island, Vermont, and Virginia
- **Tier 3 states:** Alabama, Alaska, Arizona, Arkansas, Delaware, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, North Dakota, Ohio, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, Utah, West Virginia, Wisconsin, and Wyoming

Land Use Sector

- **Tier 1 states:** California, Colorado, Maryland, New Mexico, New York, Washington
- **Tier 2 states:** Connecticut, the District of Columbia, Delaware, Hawaii, Illinois, Louisiana, Maine, Massachusetts, Michigan, Minnesota, Nevada, New Jersey, North Carolina, Oregon, Pennsylvania, Rhode Island, Texas, Utah, Vermont, and Wisconsin
- **Tier 3 states:** Alabama, Alaska, Arizona, Arkansas, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Kentucky, Mississippi, Missouri, Montana, Nebraska, New Hampshire, North Dakota, Ohio, Oklahoma, South Carolina, South Dakota, Tennessee, Virginia, West Virginia, and Wyoming

Economy-wide tiers

- **Tier 1 states:** California, Colorado, the District of Columbia, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Washington
- **Tier 2 states:** Connecticut, Delaware, Hawaii, Illinois, Maine, Michigan, Minnesota, Nevada, New Mexico, North Carolina, Pennsylvania, Vermont, and Virginia
- **Tier 3 states:** Alabama, Alaska, Arizona, Arkansas, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Montana, Nebraska, New Hampshire, North Dakota, Ohio, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, Utah, West Virginia, Wisconsin, and Wyoming

S1.5 Weighting sensitivity tests and tier stability

To test robustness to the index weighting scheme, we conducted multiple reweighting exercises. For each component weight, we increased that component by 5, 10, 15, and 20 percentage points and redistributed the remaining weight proportionally across the other components. For each reweighting, we recomputed the sectoral and economy-wide indices and re-ran k-means clustering to assess changes in tier assignments.

Across sectors, tier assignments are generally robust to the reweighting of index components. In the economy-wide index, 41 states remain in the same tier across all reweighting exercises, and the maximum number of reclassified states under any single reweighting is 9. (Table S7) Sectoral results show similar stability in electricity (32 stable, maximum 10 reclassified), transportation (34 stable, maximum 12 reclassified), buildings (28 stable, maximum 11 reclassified), and lands (36 stable, maximum 6 reclassified). The industry sector shows greater sensitivity (15 stable, maximum 28 reclassified), reflecting the low prevalence of industrial policies in most states and the resulting concentration of index values near the lower end.

The number of reclassified states generally increases with the magnitude of the weight perturbation, with the 20-percentage-point cases producing the largest changes from the baseline tiering. Figure S2 also shows that reclassifications are most responsive to changes in the Emissions Trend weight. This pattern is expected because emissions trends reflect a confluence of factors beyond climate policy, including economic structure, fuel prices, and broader macroeconomic cycles, which can introduce greater cross-state dispersion than policy adoption measures alone. The industry sector is the most sensitive overall, and most of the observed variability in industrial tier assignments is driven by Emissions Trend reweighting rather than by changes to the policy component, consistent with the limited prevalence of state industrial decarbonization policies and the resulting concentration of industry policy scores near the lower end. Full sensitivity results and replication code are available in the project repository.⁶

S2. GCAM-USA

The Global Change Analysis Model (GCAM) is a multisector integrated assessment model developed and maintained by the Joint Global Change Research Institute (JGCRI). GCAM is an open-source community model. In this study, we use GCAM-USA v8.2, a U.S.-focused version of GCAM that includes representation of the energy and economy systems for the fifty states and the District of Columbia, in addition to 31 regions outside of the United States. GCAM includes representations of the economy, energy, agriculture, and water supply across 32 geopolitical regions globally, and tracks associated greenhouse gas and air pollutant emissions, concentrations, radiative forcing, and temperature outcomes, alongside land allocation, water use, and agricultural production across land sub-regions and water basins. GCAM-USA v8.2 is calibrated to historical outcomes through 2021 and solves in five-year time steps beginning in 2025. For this study, we report modeled outcomes through 2035. Detailed documentation for GCAM and GCAM-USA v8.2 is available on the documentation website.¹⁵

Policy and action inputs used in this analysis are translated into model inputs through a state aggregation process that projects baseline trajectories, estimates policy-induced deviations from baseline, and aggregates impacts while reducing overlap across policy jurisdictions. While many impacts are applied at the state level, some are implemented at the electricity grid region level to capture interstate market interactions, or at the national level, where model structure or data

constraints require it. Several non-CO₂ emissions sources and net carbon dioxide removal from natural and working lands are calculated outside GCAM-USA and integrated to be consistent with U.S. inventories. Model inputs were developed following the process previously published in Zhao et al. (2025).¹⁶

S3. Modeling assumptions

The results of this analysis depend on many assumptions about how the United States and the world might evolve over time. This includes assumptions about economic activity, population growth, fossil fuel prices, and future energy technology costs, among other factors. In this study, the core drivers are specified consistently across scenarios. GDP grows at an average annual rate of 1.68% from 2022 through 2035, and population grows at 0.46% per year over the same period, following the U.S. Energy Information Agency's (EIA) Annual Energy Outlook Reference case.¹⁷ Natural gas prices increase at 1.3% per year and oil prices at 2.5% per year (both relative to 2022 through 2035), following the technology costs reported in the National Renewable Energy Lab's Annual Technology Baseline 2024 Moderate assumptions.¹⁸ Data center electricity demand follows the Electric Power Research Institute (EPRI) medium growth case with linear extrapolation from 2030 to 2035.¹⁹

S3.1. Existing Measures Scenario

The Existing Measures scenario represents a continuation of subnational climate policies alongside federal rollbacks that reduce or discontinue several Inflation Reduction Act and Bipartisan Infrastructure Law provisions after 2025, and assume rollbacks of several federal regulatory measures. Non-federal policies that are already in place are assumed to continue where applicable, but the removal of the California waiver results in rolling back state ZEV sales mandates and targets after 2025. This scenario corresponds directly to the "Current Policies" scenario presented in Zhao et al. (2025).¹⁶ The full list of policies and assumptions can be found in Table S8. Additional details on the modeling of the federal policy assumptions and rollbacks underlying this scenario are provided in Zhao et al. (2025).¹⁶

S3.2. Baseline Ambition scenario

The results of the State Ambition scenarios depend on assumptions about how subnational policy stringency evolves across states through 2035. *Baseline Ambition* is the central case: Tier 1, Tier 2, and Tier 3 states each implement an enhanced policy package that is consistent with their observed mitigation performance trends. Federal assumptions are held constant across all scenarios and follow the Existing Measures baseline; only non-federal assumptions vary across the State Ambition scenarios. Business as Usual (BAU) indicates no additional policy beyond the Existing Measures baseline. The *Baseline Ambition* scenario corresponds to the “Enhanced Ambition (Low)” scenario presented in Zhao et al. (2025) with small updates to the state tiering.¹⁶ The full list of policies and assumptions by tier can be found in Table S9.

S3.3. Variations of the Baseline Ambition scenario

The main text provides the policy descriptions and the rationale for each scenario modification (Results section, “Scenario Design”). Starting from the *Baseline Ambition* scenario described above, we construct additional scenario variations that modify the level of ambition implemented by each tier. These variations are new to this study and were not included in Zhao et al. (2025).¹⁶ In Zhao et al., state ambition was represented using a tiering structure that grouped states according to their expected level of climate policy ambition. In this study, that approach is updated and formalized through the sectoral tiering framework as described here. Federal assumptions remain identical to *Existing Measures* across all scenarios. The full list of policies and assumptions by tier and scenario can be found in Tables S10-13.

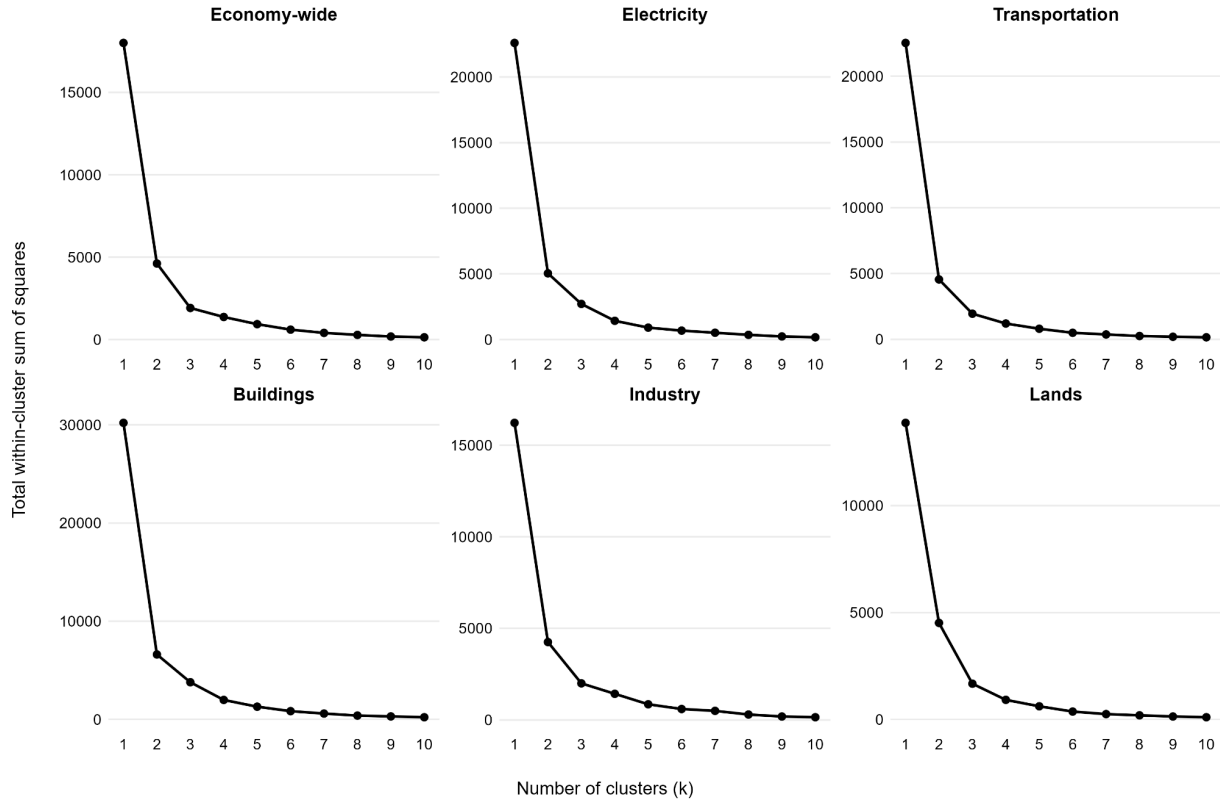


Fig. S1. Elbow method diagnostics for k-means clustering.

This figure shows the total within-cluster sum of squares (WSS) from k-means clustering as a function of the number of clusters (k), shown separately for the economy-wide index and each sectoral index. In each panel, WSS declines steeply from $k = 1$ to $k = 3$, with smaller marginal improvements thereafter, indicating that a three-cluster solution provides a parsimonious partition of states and supporting the three-tier structure used in the main analysis.

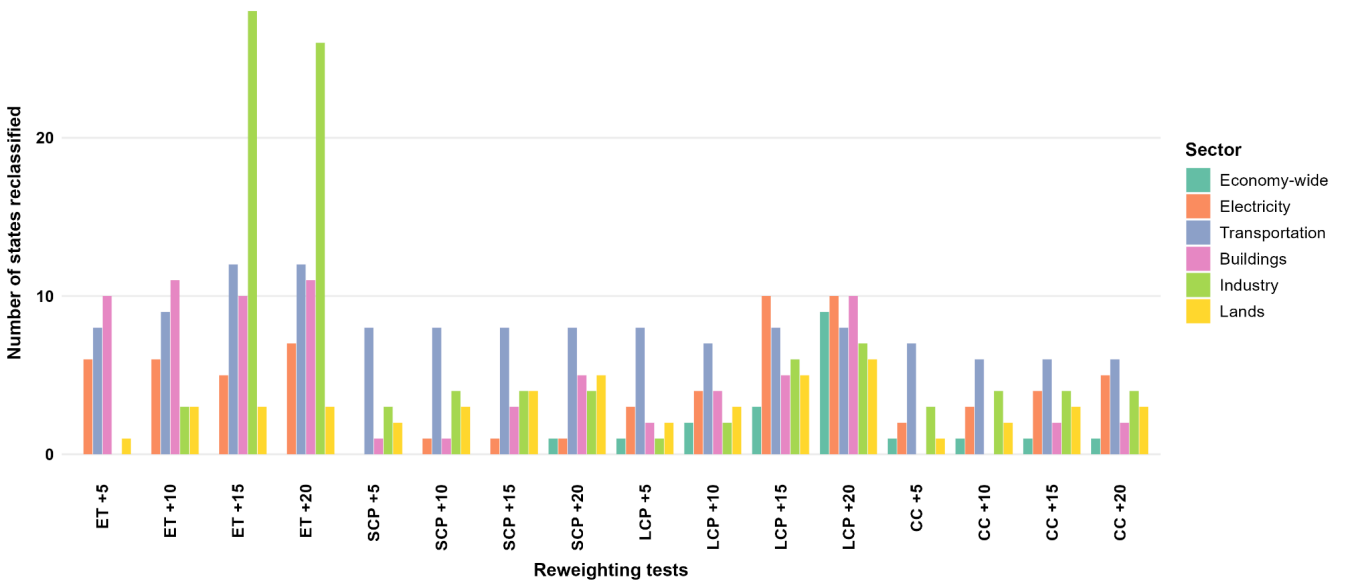


Fig. S2. Number of states reclassified under one-at-a-time component reweighting, by sector.

Reclassified states are jurisdictions whose tier assignment differs from the baseline after increasing a single component weight (ET, SCP, LCP, or CC) by 5, 10, 15, or 20 percentage points and redistributing the remaining weight proportionally across the other components, with the index recomputed and k-means clustering re-run in each scenario.

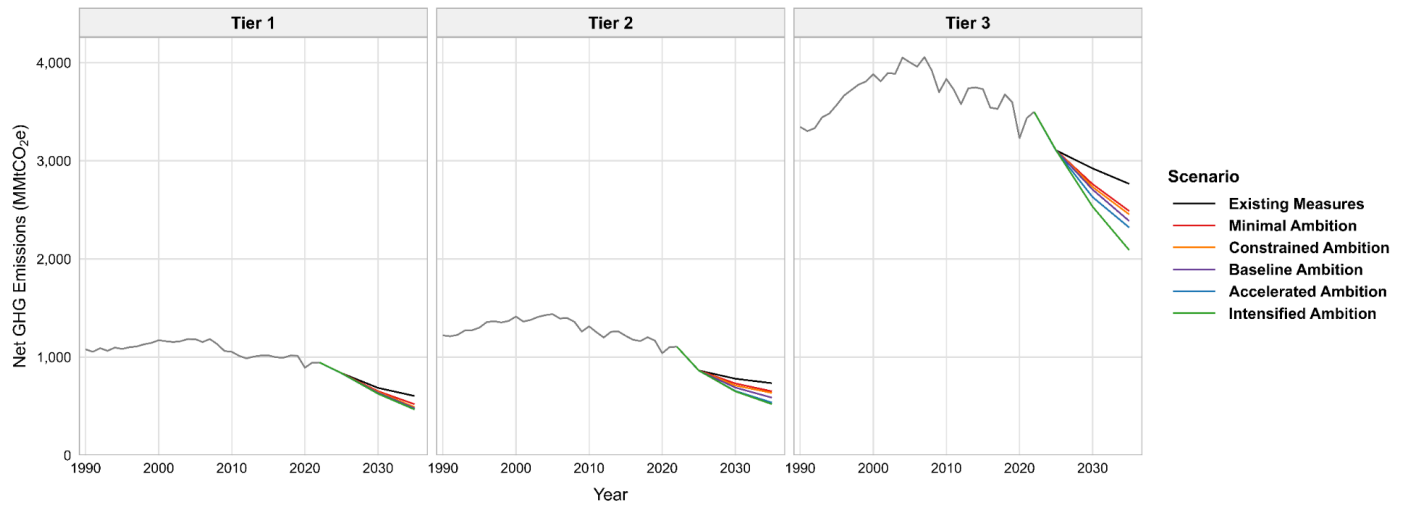


Fig. S3. Historical and Modeled Net GHG emissions (MMtCO₂e) by Tier and Scenario

Lines show modeled net GHG emissions (MMtCO₂e) by economy-wide tiers from 1990 to 2035 under the *Existing Measures* baseline and State Ambition scenarios (*Minimal, Constrained, Baseline, Accelerated, Intensified*). Historical emissions are shown in gray, sourced from the Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990-2022).²⁰

Table S1. State Tiering Index scores by state and sector, including the economy-wide aggregation.

State	Electricity	Transportation	Buildings	Industry	Lands	Economy-wide
Alabama	17.8	10	22.7	19.6	9.8	20.5
Alaska	13.8	22.3	18	15.8	22.3	2.7
Arizona	41.6	20.2	29.9	21.8	22.5	31.2
Arkansas	12.6	11	28.6	15.8	11.2	20.7
California	85.8	88.5	77.7	89.6	76.4	90.8
Colorado	73	55.6	87.3	64.1	57	66.8
Connecticut	52.4	53.3	63.8	35.5	24.3	53.2
Delaware	43	45	39.2	23.5	24.6	44.3
District of Columbia	74.6	58.6	95.2	24.2	26.4	70.4
Florida	20	13	32.1	14.5	10.8	22.9
Georgia	18.4	14.3	26.8	19.7	8.2	20.4
Hawaii	63.2	32.2	35.2	30	35.7	43.1
Idaho	4.7	8.6	15.6	20	21	27.5
Illinois	58.1	37.2	66	28.3	40.5	44.1
Indiana	26.2	15.4	21.7	18	14.2	21.4
Iowa	28.1	13.4	23.7	10.5	16.1	24.8
Kansas	17.7	12.7	10.3	16.5	17.7	23.3
Kentucky	22.9	13.1	29.1	22.8	12.3	22.1
Louisiana	22.6	12.1	36.9	23.5	33.5	27
Maine	61.3	37.1	72.1	39.3	40.8	49.2
Maryland	61.4	61.8	67	64.6	55.2	63.4
Massachusetts	66.4	63.1	83.4	54.1	40.5	68.7
Michigan	57.5	31.5	59.4	24.6	42.6	41
Minnesota	62.7	48.9	51.7	20.2	43.4	48.9
Mississippi	13.9	9.5	9.9	17.7	10.4	18.1
Missouri	24.9	15.5	20.3	16.4	16.8	22.5
Montana	23.9	12.4	27.2	19	9.1	22.8
Nebraska	15.2	12.6	26.9	12.4	19	26.5
Nevada	58.6	30.2	61	28	31.5	43.9
New Hampshire	42.9	14.3	57	21.7	18.8	29.5
New Jersey	62.5	62.6	68.6	44.4	30.1	58.9
New Mexico	56.7	44.5	51	35.8	60.1	48.5
New York	87.1	60.1	90	69.1	62.1	71.9
North Carolina	53	23.1	40.6	27	31.8	36.2
North Dakota	19.5	3.5	7.3	3.5	13.6	22.1
Ohio	36.2	17	32.9	17	9.5	24.4
Oklahoma	26.5	14.3	25	18.8	21.6	25.2
Oregon	56.1	70.1	77	54.2	33.5	66.7
Pennsylvania	33.8	36.8	51.8	33	36.6	37.8
Rhode Island	46.9	60.4	78.1	36.5	27.4	58.9
South Carolina	31.8	13.6	17.1	22.8	11	24
South Dakota	20.9	9	6.8	9.3	14.7	24.6
Tennessee	24.5	18	32.4	24.2	13.8	26.3
Texas	26.4	9.9	40.7	17.1	29.4	25.5
Utah	25.4	11.5	30.4	18.5	26.2	25.3
Vermont	43	46.3	68.1	43.2	31.7	51.6
Virginia	50.8	31	51.1	33.9	20.6	38.3
Washington	65.2	55.3	75.5	72.8	61.4	69.6
West Virginia	19.5	5.4	25.2	11.6	11.7	17.7
Wisconsin	38.3	17.1	42.6	22.6	41.4	33.3
Wyoming	12.3	12.1	9.1	15.5	2.5	16.3

Table S2. Electricity Sector Policies and Stringency Scoring Criteria.

Policy Description			Stringency Range (Low to High)		
Policy Category	Policy	Data Measured	1	2	3
Energy Plans and Targets	Clean Energy and Renewable Portfolio Standards (2025-2035 goal)*	Target(s), year(s), and utility types covered	Old RPS (not updated) or less than 30% goal	31-50% goal	Goal of 51% or more
	Clean Energy and Renewable Portfolio Standards (2040-onwards goal)*	Target(s), year(s), and utility types covered	-	-	100% Clean Goal
	Electricity Greenhouse Gas Emissions Reduction Targets	Target(s) and year(s)	Exists	-	-
	Clean Energy Plans	Existence of a state-level clean energy plan	Exists	-	-
Clean Energy Generation	Distributed Generation Carve-out	Number of SPOT policy components	Exists	-	-
	Net Metering	Number of SPOT policy components	Exists	-	-
	Shared Renewables	Number of SPOT policy components	Exists	-	-
	Community Choice Aggregation	Existence of CCA	Exists	-	-
Transmission, Distribution, and Energy Storage	Energy Storage Targets	Target(s) and year(s)	Exists	-	-
	Interconnection Standards	Freeing the Grid state grades	D	C	A, B
Coal Retirement	Coal Phaseouts	Approach to phase-out and starting year	2045 or after	2031 - 2044	2030 or earlier
	Coal Securitization	Authorization of securitization for coal plant retirement	Exists	-	-

*We disaggregated RPS targets into near-term (2025–2035) and long-term (2040+) goals to reflect their distinct policy significance. While reported jointly in ClimateXChange, many states have only one, and near-term targets are more indicative of actionable ambition.

Table S3. Transportation Sector Policies and Stringency Scoring Criteria.

Policy Description			Stringency Range (Low to High)		
Policy Category	Policy	Data Measured	1	2	3
Light-Duty Vehicles	Low-Emission Vehicle (LEV) Standards	LEV or ZEV policy, with percentages and years	Adoption of California's Low-Emission Vehicle regulations	ZEV policy not reaching 100% by 2035	ZEV policy reaching 100% of sales by 2035
	Electric Vehicle Rebates	Rebate amount and covered vehicle types	<\$2,000 rebate for new BEVs	\$2,000-\$4,000 rebate for new BEVs	>\$4,000 rebate for new BEVs or any rebates for used BEVs or additional income-based rebates
Medium- and Heavy-Duty Vehicles	Medium- and Heavy-Duty Vehicle (MHDV) Zero-Emission Vehicle (ZEV) Mandates	Adoption of California's Advanced Clean Trucks regulations	-	-	Adoption
	Medium- and Heavy-Duty Electric Vehicle (EV) Rebates	Existence of rebates	-	-	Exists
Procurement Targets	Public Fleet Electric Vehicle (EV) Procurement Target	Target type	Must prioritize EVs for public fleet purchases	-	LDV or MHDV standard
	Electric Bus Procurement Target	Existence of a target	-	-	Exists
EV Charging Infrastructure	Electric Vehicle (EV) Charging Infrastructure Rebates	Covered chargers	-	Rebates for only Level 1 or Level 2 chargers	Rebates for DC chargers or additional income-based rebates
	Electric Vehicle (EV) Charging Infrastructure Requirements	Covered construction type	Parking areas	Commercial buildings	Residential buildings
	Medium- and Heavy-Duty EV Supply Equipment (EVSE) Requirements	Existence of a mandate	-	-	Exists
Transportation Plans and Targets	Electric Vehicle (EV) Charging Infrastructure Plans	Existence of a state-level plan	Exists	-	-
	Transportation Greenhouse Gas Emissions Reduction Targets	Existence of a target	Exists	-	-
	Low Carbon Fuel Standards	Existence of state-level policies	-	-	Exists
Public and Active Transportation	Bicycle Friendly States	League of American Bicyclists 2024 ranking	Rank of 1-10	-	-
	Public Transportation Funding*	Public transport funding score, NRDC metric	Score above 50% of the total possible score	-	-
	ebike Rebates*	Rebate amount	≤ \$500 rebate	> \$500 rebate or additional income-based rebates	-
	VMT Reduction Policies*	Existence of state-level policies	-	-	Exists

*These policies were not included in the ClimateXChange database and were compiled by the authors from state statutes, regulatory filings, and publicly available agency sources. The sources by state are specified in the SCP dataset.

Table S4. Building Sector Policies and Stringency Scoring Criteria.

Policy Description			Stringency Range (Low to High)		
Policy Category	Policy	Data Measured	1	2	3
Building Codes	Residential Energy Codes	Most recent energy code adopted	< 2012 IECC	2012-2018 IECC	≥ 2021 IECC or state standard
	Commercial Energy Codes	Most recent energy code adopted	< 2012 IECC/ 2010 ASHRAE	2012-2018 IECC/ 2010-2016 ASHRAE	≥ 2021 IECC/ 2019 ASHRAE or state standard
	Stretch Energy Codes	Most recent stretch code adopted	< 2012 IECC/ 2010 ASHRAE	2012-2018 IECC/ 2010-2016 ASHRAE	≥ 2021 IECC/ 2019 ASHRAE or state standard
Building Standards	Appliance Standards	Number of products covered	1-10 appliances	11-25 appliances	> 25 appliances
	Building Performance Standard	Existence of a standard	-	-	Exists
	Clean Heat Standard	Existence of a standard	-	-	Exists
Energy Efficiency	Energy Efficiency Resource Standard (EERS) for electric utilities*	Annual energy savings target	< 1%	1-2%	> 2%
	Energy Efficiency Resource Standard (EERS) for gas utilities*	Annual energy savings target	< .5%	.5-1%	> 1%
	Property Assessed Clean Energy (PACE)	Existence of PACE-enabling legislation or active PACE programs	Enacting legislation, but no active programs	Existence of residential or commercial programs	Existence of residential and commercial programs
	Weatherization Funding	Number of SPOT policy components	1 policy component	2-3 policy components	4 policy components
Building Electrification	All-Electric Buildings	Existence of a policy or standard	-	-	Exists

*We disaggregated Energy Efficiency Resource Standards (EERS) into those applicable to gas utilities and electric utilities to reflect differences in mitigation impact, placing a higher benchmark for electricity EERS.

Table S5. Industry Sector Policies and Stringency Scoring Criteria.

Policy Description			Stringency Range (Low to High)		
Policy Category	Policy	Data Measured	1	2	3
Industrial Decarbonization	Buy Clean Requirements	Existence of Buy Clean requirements	-	-	Exists
	Manufacturing GHG Emissions Standard or Target*	Existence of a manufacturing GHG emissions standard or target for at least one manufacturing product	-	-	Exists
	Cap-and-trade program*	Existence of a cap-and-trade program	-	-	Exists
	Industrial Decarbonization Incentives*	Existence of an industrial decarbonization grant or tax incentive program	-	-	Exists
	Green Hydrogen Incentives*	Existence of a green hydrogen incentive program	-	-	Exists
F-Gas Regulations	Hydrofluorocarbon (HFC) Regulations		-	-	Exists
	Sulfur Hexafluoride (SF6) Regulations		-	-	Exists
Oil and Gas Regulations	Oil and Gas Methane Regulations		-	-	Exists
	Fracking Bans		-	-	Exists
Waste Management	Landfill Methane Regulations		-	-	Exists
	Food Waste Bans and Targets		-	-	Exists

*These policies were not included in the ClimateXChange database and were compiled by the authors from state statutes, regulatory filings, and publicly available agency sources. The sources by state are specified in the SCP dataset.

Table S6. Lands Sector Policies and Stringency Scoring Criteria.

Policy Description			Stringency Range (Low to High)		
Policy Category	Policy	Data Measured	1	2	3
Plans and Targets	Sectoral Planning*	Type of initiative	Taskforce	Planning document	-
	Workforce Training*	Existence of program	Exists	-	-
	Research, Data, and Inventories*	GHG inventory or other data	Exists	-	-
	Smart Growth Policies*	NRDC smart growth score	Score >50% total possible score	-	-
	Conservation Target*	Type of target(s)	Maintenance of existing conservation lands	Tree planting target	Goal of conserving explicit share of state lands
	Conservation Funding*	Funding structure	Inclusion in offset program	Tax incentives for easements	Expanding funding or establishing recurring funds
Soil Health and Cover Crops	Agriculture Financial Incentives	Funding amount	-	-	Exists
	Agriculture Technical Assistance Programs	Existence of programs	-	Exists	-
Forests	Afforestation and Reforestation Incentives*	Funding amount	-	-	Exists
	Afforestation Technical Assistance Programs*	Existence of programs	-	Exists	-
	Wildfire Prevention Funding*	Funding amount	-	-	Exists
	Wildfire Prevention Technical Assistance*	Existence of programs	-	Exists	-
Methane	Manure Management*	Funding type	-	Add-on to federal funding	State-led program
	Enteric Fermentation Mitigation*	Funding type	-	Add-on to federal funding	State-led program
	Rice*	Funding type	-	Add-on to federal funding	State-led program

*These policies were not included in the ClimateXChange database and were compiled by the authors from state statutes, regulatory filings, and publicly available agency sources. The sources by state are specified in the SCP dataset.

Table S7. Tier stability under component reweighting. “Stable states” are states whose tier assignment does not change across any reweighting exercise (relative to the baseline weights), after recomputing the index and re-running k-means clustering for each scenario. “Reclassified states” are the number of states whose tier differs from the baseline tiering under a given reweighting scenario. Results are reported for 51 jurisdictions (50 states plus DC) across 16 one-at-a-time reweighting scenarios.

Sector	States by Tier (T1/T2/T3)	Stable states (all tests)	Stable Tier 1	Stable Tier 2	Stable Tier 3	Maximum reclassified states (any test)	Mean reclassified states
Economy-wide	10/13/28	41	9	11	21	9	1.3
Electricity	16/12/23	32	3	6	23	10	4.3
Transportation	11/11/29	34	3	6	25	12	8.1
Buildings	14/13/24	28	7	6	15	11	4.8
Industry	7/12/32	15	5	4	6	28	6.4
Lands	6/20/25	36	6	12	18	6	3.1

Table S8. Summary of Existing Measures scenario assumptions in GCAM-USA.

Sector	Federal	Non-federal
Electricity	<ul style="list-style-type: none"> ● IRA clean electricity PTC and ITC: rolled back after 2025 ● Residential clean energy credit: rolled back after 2025 ● PTC for existing nuclear: continues through 2033 ● Energy infrastructure reinvestment financing: rolled back after 2025 ● 45Q extension for captured CO₂: rolled back after 2025 ● EPA power plant standards (CAA 111(b) and 111(d)): rolled back after 2025 	<ul style="list-style-type: none"> ● Renewable portfolio standards: current state targets ● Cap and trade: RGGI modeled as 50% power sector emissions reduction below 2020 by 2035 in participating states; California and Washington caps also modeled ● Coal phaseout: scheduled coal retirements through 2035
Transportation	<ul style="list-style-type: none"> ● IRA clean vehicle credit 30D rolled back after 2025 ● Alternative refueling property credit rolled back after 2026 ● Commercial clean vehicle credit 45W rolled back after 2025 ● Clean fuel production credit 45Z extended through 2030 ● BIL charging and fueling and related programs rolled back after 2025 ● CAFE standards for LDVs rolled back after 2025 ● GHG standards for freight trucks rolled back after 2025 	<ul style="list-style-type: none"> ● LDV ZEV sales mandates and targets rolled back after 2025 ● Freight truck ZEV sales mandates and targets rolled back after 2025 ● LDV ZEV incentives modeled as reductions in per vehicle capital cost, equivalent to a national average EV capital cost reduction of \$826 per vehicle
Buildings	<ul style="list-style-type: none"> ● Energy efficient commercial building deduction rolled back after 2026 ● Energy efficient home credits and rebates 25C, 13304, 50121 rolled back after 2025 ● High efficiency home rebate program continues through 2031 	<ul style="list-style-type: none"> ● Energy efficiency resource standards current state EERS modeled via reduced state building service demands
Industry and Others	<ul style="list-style-type: none"> ● 45Q extension for captured CO₂ rolled back after 2025 ● Clean hydrogen production credit 45V rolled back after 2027 ● Advanced energy project manufacturing credit 48C rolled back after 2025 ● Advanced industrial facilities deployment program rolled back after 2025 ● Methane emissions reduction program rolled back after 2025 ● EPA oil and gas methane standards rolled back after 2025 ● AIM Act HFC phasedown continues ● LULUCF provisions rolled back after 2025 	<ul style="list-style-type: none"> ● Methane incentives and regulations reductions limited to measures achievable at \$0 per tCO₂e or below on EPA MAC curves

Table S9. Non-federal policy assumptions under Baseline Ambition.

Sector	Policy	Tier 1	Tier 2	Tier 3
Electricity	Renewable portfolio standards	65% by 2035	50% by 2035	20% by 2035
	Clean electricity standards	80% by 2035	BAU	BAU
	Coal phaseout policies	Phaseout by 2030	Phaseout by 2035	Phaseout by 2040
Transportation	Light-duty vehicle electrification policies (to support ACC II targets)	100% EV sales by 2038	100% EV sales by 2041	100% EV sales by 2044
	Medium- and heavy-duty vehicle electrification policies (to support ACT targets)	ACT-equivalent sales targets with a 3-year delay	BAU	BAU
	Vehicle miles traveled (VMT) reduction policies	1.25% annual VMT per capita reduction by 2035	0.75% annual VMT per capita reduction by 2035	BAU
	Low-carbon fuel standards	20% in 2030 and 25% in 2035	BAU	BAU
Buildings	Enhanced energy efficiency resource standards	4% annual efficiency savings by 2030	4% annual efficiency savings by 2030	BAU
	Zero-emission appliance standards	100% electric space and water heating sales by 2035	100% electric space and water heating sales by 2040	BAU
	Zero-emission construction standards	100% new electric construction by 2035	100% new electric construction by 2035	BAU
Industry	Cement CCS targets	40% of cement production with CCS by 2035	20% by 2035	10% by 2035
Methane	Oil and gas methane regulations	\$60 per tCO ₂ e	\$30 per tCO ₂ e	\$0 per tCO ₂ e
	Landfill waste methane regulations	\$60 per tCO ₂ e	\$40 per tCO ₂ e	\$20 per tCO ₂ e
	Enhanced waste diversion efforts	60% reduction in landfill waste by 2035	40% by 2035	20% by 2035
Other	HFC regulations	Adopt SNAP and RMP	Adopt SNAP and RMP	BAU

Table S10. Non-federal policy assumptions under Minimal Ambition. Minimal Ambition assumes a one-tier downward shift for Tier 1 and Tier 2 relative to Baseline Ambition. Tier 1 states implement Tier 2 levels, Tier 2 states implement Tier 3 levels, and Tier 3 remains at Tier 3.

Sector	Policy	Tier 1	Tier 2	Tier 3
Electricity	Renewable portfolio standards	50% by 2035	20% by 2035	20% by 2035
	Clean electricity standards	BAU	BAU	BAU
	Coal phaseout policies	Phaseout year 2035	Phaseout year 2040	Phaseout year 2040
Transportation	Light-duty vehicle electrification policies (ACC II)	100% EV sales by 2041	100% EV sales by 2044	100% EV sales by 2044
	Medium and heavy-duty vehicle electrification policies (ACT)	BAU	BAU	BAU
	Vehicle miles traveled reduction policies	0.75% annual reduction by 2035	BAU	BAU
	Low-carbon fuel standards	BAU	BAU	BAU
Buildings	Enhanced energy efficiency resource standards	4% annual savings by 2030	BAU	BAU
	Zero-emission appliance standards	100% electric heating and water heating sales by 2040	BAU	BAU
	Zero-emission construction standards	100% new electric construction by 2035	BAU	BAU
Industry	Cement CCS targets	20% by 2035	10% by 2035	10% by 2035
Methane	Oil and gas methane regulations (EPA MAC curve threshold)	\$30/tCO _{2e}	\$0/tCO _{2e}	\$0/tCO _{2e}
	Landfill waste methane regulations (EPA MAC curve threshold)	\$40/tCO _{2e}	\$20/tCO _{2e}	\$20/tCO _{2e}
	Enhanced waste diversion efforts	40% reduction in landfill waste by 2035	20% by 2035	20% by 2035
Other	HFC regulations	Adopt SNAP and RMP	BAU	BAU

Table S11. Non-federal policy assumptions under Constrained Ambition. Constrained Ambition holds Tier 1 at its Baseline Ambition level but assumes Tier 2 states implement additional policies at Tier 3 levels. Tier 3 remains at Tier 3.

Sector	Policy	Tier 1	Tier 2	Tier 3
Electricity	Renewable portfolio standards	65% by 2035	20% by 2035	20% by 2035
	Clean electricity standards	80% by 2035	BAU	BAU
	Coal phaseout policies	Phaseout year 2030	Phaseout year 2040	Phaseout year 2040
Transportation	Light-duty vehicle electrification policies (ACC II)	100% EV sales by 2038	100% EV sales by 2044	100% EV sales by 2044
	Medium and heavy-duty vehicle electrification policies (ACT)	ACT-equivalent EV sales targets with a 3-year delay	BAU	BAU
	Vehicle miles traveled reduction policies	1.25% annual reduction by 2035	BAU	BAU
	Low-carbon fuel standards	20% in 2030 and 25% in 2035	BAU	BAU
Buildings	Enhanced energy efficiency resource standards	4% annual savings by 2030	BAU	BAU
	Zero-emission appliance standards	100% electric heating and water heating sales by 2035	BAU	BAU
	Zero-emission construction standards	100% new electric construction by 2035	BAU	BAU
Industry	Cement CCS targets	40% by 2035	10% by 2035	10% by 2035
Methane	Oil and gas methane regulations (EPA MAC curve threshold)	\$60/tCO _{2e}	\$0/tCO _{2e}	\$0/tCO _{2e}
	Landfill waste methane regulations (EPA MAC curve threshold)	\$60/tCO _{2e}	\$20/tCO _{2e}	\$20/tCO _{2e}
	Enhanced waste diversion efforts	60% reduction in landfill waste by 2035	20% by 2035	20% by 2035
Other	HFC regulations	Adopt SNAP and RMP	BAU	BAU

Table S12. Non-federal policy assumptions under Accelerated Ambition. Accelerated Ambition assumes Tier 2 states implement Tier 1 levels while Tier 1 remains Tier 1 and Tier 3 remains Tier 3.

Sector	Policy	Tier 1	Tier 2	Tier 3
Electricity	Renewable portfolio standards	65% by 2035	65% by 2035	20% by 2035
	Clean electricity standards	80% by 2035	80% by 2035	BAU
	Coal phaseout policies	Phaseout year 2030	Phaseout year 2030	Phaseout year 2040
Transportation	Light-duty vehicle electrification policies (ACC II)	100% EV sales by 2038	100% EV sales by 2038	100% EV sales by 2044
	Medium and heavy-duty vehicle electrification policies (ACT)	ACT-equivalent EV sales targets with a 3-year delay	ACT-equivalent EV sales targets with a 3-year delay	BAU
	Vehicle miles traveled reduction policies	1.25% annual reduction by 2035	1.25% annual reduction by 2035	BAU
	Low-carbon fuel standards	20% in 2030 and 25% in 2035	20% in 2030 and 25% in 2035	BAU
Buildings	Enhanced energy efficiency resource standards	4% annual savings by 2030	4% annual savings by 2030	BAU
	Zero-emission appliance standards	100% electric heating and water heating sales by 2035	100% electric heating and water heating sales by 2035	BAU
	Zero-emission construction standards	100% new electric construction by 2035	100% new electric construction by 2035	BAU
Industry	Cement CCS targets	40% by 2035	40% by 2035	10% by 2035
Methane	Oil and gas methane regulations (EPA MAC curve threshold)	\$60/tCO _{2e}	\$60/tCO _{2e}	\$0/tCO _{2e}
	Landfill waste methane regulations (EPA MAC curve threshold)	\$60/tCO _{2e}	\$60/tCO _{2e}	\$20/tCO _{2e}
	Enhanced waste diversion efforts	60% reduction in landfill waste by 2035	60% by 2035	20% by 2035
Other	HFC regulations	Adopt SNAP and RMP	Adopt SNAP and RMP	BAU

Table S13. Non-federal policy assumptions under Intensified Ambition. Intensified Ambition assumes Tier 2 states implement Tier 1 levels and Tier 3 states implement Tier 2 levels. Tier 1 remains Tier 1.

Sector	Policy	Tier 1	Tier 2	Tier 3
Electricity	Renewable portfolio standards	65% by 2035	65% by 2035	50% by 2035
	Clean electricity standards	80% by 2035	80% by 2035	BAU
	Coal phaseout policies	Phaseout year 2030	Phaseout year 2030	Phaseout year 2035
Transportation	Light-duty vehicle electrification policies (ACC II)	100% EV sales by 2038	100% EV sales by 2038	100% EV sales by 2041
	Medium and heavy-duty vehicle electrification policies (ACT)	ACT-equivalent EV sales targets with a 3-year delay	ACT-equivalent EV sales targets with a 3-year delay	BAU
	Vehicle miles traveled reduction policies	1.25% annual reduction by 2035	1.25% annual reduction by 2035	0.75% annual reduction by 2035
	Low-carbon fuel standards	20% in 2030 and 25% in 2035	20% in 2030 and 25% in 2035	BAU
Buildings	Enhanced energy efficiency resource standards	4% annual savings by 2030	4% annual savings by 2030	4% annual savings by 2030
	Zero-emission appliance standards	100% electric heating and water heating sales by 2035	100% electric heating and water heating sales by 2035	100% electric heating and water heating sales by 2040
	Zero-emission construction standards	100% new electric construction by 2035	100% new electric construction by 2035	100% new electric construction by 2035
Industry	Cement CCS targets	40% by 2035	40% by 2035	20% by 2035
Methane	Oil and gas methane regulations (EPA MAC curve threshold)	\$60/tCO ₂ e	\$60/tCO ₂ e	\$30/tCO ₂ e
	Landfill waste methane regulations (EPA MAC curve threshold)	\$60/tCO ₂ e	\$60/tCO ₂ e	\$40/tCO ₂ e
	Enhanced waste diversion efforts	60% reduction in landfill waste by 2035	60% by 2035	40% by 2035
Other	HFC regulations	Adopt SNAP and RMP	Adopt SNAP and RMP	Adopt SNAP and RMP

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