TECHNICAL APPENDIX

TOWARD 2035:

Forging a High-Ambition U.S. Climate Pathway

SCHOOL OF PUBLIC POLICY
CENTER FOR GLOBAL SUSTAINABILITY

SEPTEMBER 2024

AUTHORS:

Alicia Zhao, Kowan O'Keefe, Shannon Kennedy, Matthew Binsted, Camryn Dahl, Claire Squire, Kiara Ordonez Olazabal, Adriana Bryant, Jordan Snarski, Dmitry Churlyaev, Steven J. Smith, Gail Chalef, Nate Hultman, and Ryna Cui

This Technical Appendix is an updated version of the Supplemental Information from our recent *npj Climate Action* article: High-ambition climate action in all sectors can achieve 65% greenhouse gas emissions reduction in the United States by 2035.

Table of Contents

1. Overview of GCAM-USA-CGS

Our analysis uses a version of the open-source Global Change Analysis Model (GCAM) to estimate the aggregate impact of federal and non-federal climate policies and actions on economy-wide emissions reductions in the United States. Specifically, we use GCAM-USA, a state-level version of GCAM. We refer to the version of GCAM-USA used in this study as GCAM-USA-CGS.

GCAM is an integrated assessment model (IAM) of the energy, land, water, climate, and socioeconomic systems. The global version of GCAM groups the world's countries into 32 geopolitical regions with representation of the energy and socioeconomic systems for each region. The United States is one of the 32 regions. GCAM represents the global climate system and uses 235 water basins and 384 land regions to represent global water and land systems. GCAM tracks emissions and sinks of carbon dioxide (CO_2), 16 other GHGs, and several air pollutants.

The state-level version of GCAM used in this analysis, GCAM-USA, disaggregates the U.S. energy and economy components into 50 states and the District of Columbia while maintaining the same level of detail as GCAM for water and land sectors. The energy system in GCAM-USA has representation of depletable primary energy sources including coal, gas, oil, and uranium, in addition to renewable resources including biomass, hydropower, solar, wind, and geothermal. Energy transformation processes like oil refining and electricity generation are represented at the state level in GCAM-USA. These energy carriers, in turn, are used to deliver services to state-level end users in the buildings, transportation, and industrial sectors. The electric power sector includes representation of a range of electricity generation technologies, including those fueled by fossil fuels and bioenergy (with and without CCS), renewables, and nuclear.

GCAM-USA is a market equilibrium model. The model solves for equilibrium in each period by finding a set of market prices such that supplies and demands are equal to one another in all markets as model actors adjust the quantities of the commodities they demand and supply. GCAM operates in 5-year time increments, with each new period starting from the conditions that emerged in the previous period, and with most technologies being vintaged such that a portion of existing stocks in each period carry over into future time periods.

GCAM-USA-CGS is based on the open-source release of GCAM-USA 6.0.[1] GCAM-USA-CGS has been updated for the purposes of this study to reflect changes such as the most recent estimates of future renewable energy costs.[2] The model is also calibrated to the latest non-CO_2 marginal abatement cost curves from the U.S. Environmental Protection Agency (EPA).[3]

2. Summary of modeling approach

2.1. Core scenarios

The *Current Policies* scenario includes the climate and energy provisions of the Inflation Reduction Act (IRA), the Bipartisan Infrastructure Legislation (BIL), and several other federal and non-federal climate policy actions. The IRA, along with additional policies and actions from Congress, the federal government, states, cities, and businesses, collectively provide a major boost to climate action in the United States. On their own, these policies will not be enough to put the United States on a path to meet its 2030 climate target and achieve ambitious reductions through 2035 and beyond. Thus, our *Enhanced Ambition* scenario models greenhouse gas (GHG) emissions reductions achievable under a comprehensive society-wide climate strategy that builds upon the policy framework in the *Current Policies* scenario with enhanced non-federal and federal action. Specifically, the *Enhanced Ambition* scenario assumes enhanced action from non-federal actors – states, cities, and businesses – with additional federal regulatory actions to achieve an ambitious new 2035 emissions reduction target. Both scenarios include top-down and bottom-up policy representation, with the latter building on previously developed methodology for aggregating non-federal actions to the state-level for implementation in GCAM-USA.[4-8] Detailed modeling assumptions for representation in GCAM-USA-CGS for these and all other policies in both scenarios are shown in Tables S2-S5.

2.2. Policy representation

Policy representation in our modeled scenarios builds upon bottom-up aggregation tools and data analysis to evaluate and quantify the impacts of policies and climate actions in isolation and within specific sectors. Throughout, we took care to avoid potential double counting of potential emissions reduction drivers from nested governance levels. We then used this information in GCAM-USA-CGS to estimate the economy-wide implications of associated policies. We use a modeling approach consistent with previous analyses, including Accelerating America's Pledge (2019), An All-In Climate Strategy Can Cut U.S. Emissions by 50% by 2030 (2021), Blueprint 2030 (2021), An All-In Pathway to 2030 (2023), and our recent *npj Climate Action* journal article.[4–7,9,10]

All modeled policies in GCAM-USA-CGS are implemented at the state and/or national levels. Policies and actions from city governments, businesses, and institutions were aggregated to the state level or assumed to be embedded within or supportive of the state and/or national level policy representation in the model, and therefore not explicitly modeled to remove the risk of double counting potential emissions reductions. Descriptions of policy representation in GCAM-USA-CGS can be found in Tables S2-S5.

Model parameters in GCAM-USA-CGS were varied according to information from our bottom-up aggregation analysis or they were changed directly for policy drivers where bottom-up aggregation was either not feasible or not necessary in the case of small-scale potential impacts. The purpose of this analysis is to assess the national emissions reduction potential in the United States for the policies modeled in our scenarios. Accordingly, non-federal policies and actions are only modeled to the extent that doing so would have a meaningful impact on the national-level emissions outcome.

2.3. Policy interactions and implementation

In our study, state-level policies were largely modeled to enhance federal policies. We generally modeled federal actions and incentives first and then layered on other actions. We took care to avoid double counting in cases where it may be applicable. For example, in modeling LDV electrification, we model the federal- and state-level EV tax credits first to see how much electrification would be driven by changes in cost. Then, we layer on the state-level sales targets to close the gap for the states that are still not meeting their targets. Some states already meet their targets in certain years with the tax credits, so we do not implement any additional sales share increase in such cases. In the power sector, we first model the IRA clean energy tax credits and investments, and any federal power plant regulations. We then layer on state-level RPS to deploy any additional renewable generation that is needed. For the PJM grid region, we double-check the power sector emissions to see if they comply with RGGI targets. If they already exceed the RGGI targets, then we do not model any additional policies. If they fall short of the RGGI targets, then we model an emissions constraint for the power sector on top of the other bottom-up policies.

Additionally, in cases where there is ambiguity around the interpretation of certain policies, we opted for the climate-smart interpretation of these provisions. In interpreting BIL, for example, some of the provisions could potentially fund highway repairs instead of EV infrastructure; however, we chose to assume that the funding would go toward EV infrastructure.

We also note that the modeling assumes full implementation of binding targets and incentives. In reality, we recognize that the presence of a binding target does not necessarily entail that the target will be met. Furthermore, in the case of the IRA provisions, full implementation of the investments may not be achieved if non-federal actors do not take advantage of these provisions or use them appropriately.

3. Modeling assumptions

3.1. Core model assumptions

The results of this study depend on many assumptions about how the U.S. and the world might evolve in the future. This study uses a set of core assumptions for drivers including economic growth, population growth, fossil fuel prices, demand impacts of the COVID-19 pandemic, and technology costs (Table S1). Our core assumptions draw from a set of data sources that are referenced in other parts of this appendix, for example, U.S. Energy Information Agency's (EIA) Annual Energy Outlook (AEO)[11] and Rhodium Group.[12] Economic impacts associated with COVID-19 in 2020 and subsequent recovery in subsequent years have also been incorporated into these assumptions.

Table S1. Core modeling assumptions in GCAM-USA-CGS

Drivers	**Scenario assumptions**
Economic Growth	Overall gross domestic product (GDP) decreases by 3.5% year-on-year in 2020, then increases by 1.68% per year on average through 2035.
Population Growth	Population grows by 0.46% per year on average through 2035.
Fuel Prices	Gas price is assumed to drop by 19.5% year-on-year in 2020, increase by 89% in 2021, then increase at an average rate of 1.3% per year through 2035. Oil price is assumed to drop by 33.9% year-on-year in 2020, increase by 78.4% in 2021. Prices increase at an average rate of 2.5% per year between 2021 and 2035.
Transportation Energy Demand	Transport sector energy demand is assumed to decrease by 6.9% from 2015 levels in 2020, with recovery through 2030.
Industry Energy Demand	Industry sector energy demand is assumed to decrease by 3.1% from 2015 levels in 2020, with recovery through 2030.
Buildings Energy Demand	Buildings sector energy demand is assumed to decrease by 1.9% from 2015 levels in 2020, with recovery through 2030.
Technology Costs	Technology costs are updated with the National Renewable Energy Laboratory (NREL) Annual Technology Baseline 2023 assumptions.[13]

3.2. State tiering

State-level climate action in the United States varies considerably from across the country. For example, some states aim to achieve 100% ZEV sales in light-duty vehicle (LDV) markets by 2035, while other states have less ambitious ZEV sales targets, and some lack ZEV sales targets entirely. Therefore, to account for the unequal ambition and urgency with which states implement policies and actions to reduce emissions, and to facilitate our scenario analysis, we group states into three different tiers.

State-level tiering reflects the propensity of a state to take further climate action based on the strength of its past and current climate policies. Tier 1 states have been leading the way on climate action in the United States and we assume that they will adopt a full range of climate policies in deep decarbonization scenarios. Tier 2 states have some policies in place but tend to move slower than Tier 1 states on climate action. Thus, we assume that they will adopt some of the additional climate policies in deep decarbonization scenarios, although at a slower rate than Tier 1 states. The rest of the states, categorized as Tier 3, have taken limited steps to advance climate action, and are assumed to continue at a slow pace. We, therefore, assume limited additional policy action in deep decarbonization scenarios, and typically on slower time scales than we assume for Tier 1 and Tier 2 states.

The tier system is implemented as either a difference in the speed of policy uptake or as a difference in the target set. For example, tiering for state-level EV sales targets is based on the speed of uptake. Tier 1 states meet the Advanced Clean Cars II and Advanced Clean Trucks targets, while Tier 2 and Tier 3 states achieve the same targets but lag by 3 and 6 years, respectively. For RPS, where implementation is based on differences in the target itself, collectively Tier 1 states achieve 75% renewable generation, Tier 2 states achieve 55%, and Tier 3 states achieve 20%. Targets for the different tiers are estimated based on high-achieving states in each tier. See Tables S2-S5 for details on policy assumptions and the level of adoption for each tier. Some of the markers that we use to categorize states as Tier 1, Tier 2, or Tier 3 include their on-the-books climate policies (including RPS and EERS), vocal leadership in support of climate action, the ambition of their emission reduction targets or standards, and their memberships in leadership organizations like the U.S. Climate Alliance. A full list of states categorized into Tier 1, Tier 2, and Tier 3 are listed below and Figure S1 shows a map of all states by tier.

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

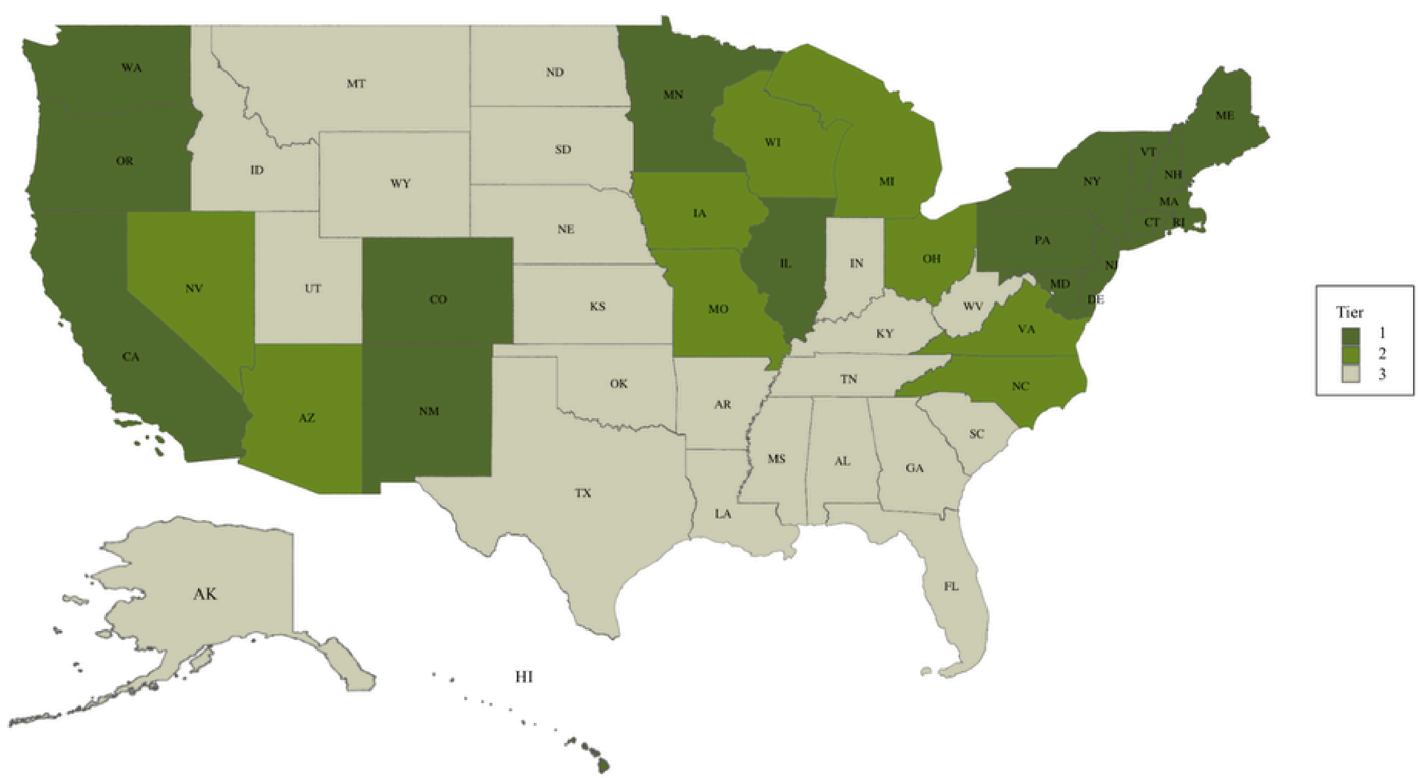

Figure S1. Tier 1, Tier 2, and Tier 3 states.

3.3. Modeled IRA provisions

Both scenarios include many of the climate and energy provisions of the IRA, which are listed below. Detailed assumptions for these policies are described in Tables S2-S5.

Electricity sector

- Section 13101: Production tax credit (PTC)
- Section 13102: Investment tax credit (ITC) extension
- Sections 13701 & 13702: New clean electricity PTC and ITC
- Section 13302: Residential clean energy credit
- Section 13015: PTC for existing nuclear
- Section 50144: Energy infrastructure reinvestment financing
- Section 13104 – 45Q: Extension of credits for captured CO_2

Transportation sector

- Section 13401 – 30D: Clean vehicle credit
- Section 13404: Alternative refueling property credit
- Section 13403 – 45W: Commercial clean vehicle credit
- Sections 13201, 13202, and 13203: Extension of incentives for biofuels

Buildings sector

- Section 13303: Energy efficient commercial building deduction
- Sections 13301 – 25C, 13304, and 50121: Energy efficient home improvement credit, Energy efficient home credit, and Home energy efficiency credit
- Section 51022: High-efficiency home rebate program

Industry and other sectors

- Section 13104 – 45Q: Extension of credits for captured CO_2
- Section 13204 – 45V: Production credit for clean hydrogen
- Section 13501 – 48C: Manufacturing investment tax credit for advanced energy projects
- Section 50161: Advanced industrial facilities deployment program
- Section 60113: Methane emissions reduction program

3.4. Electricity sector modeling assumptions

In this and subsequent sections, the modeling assumptions are provided in tables that identify the type of policy (federal vs. non-federal), the specific portion of the policy (where relevant), and a column with a description of the assumptions used in the *Current Policies* scenario, followed by a description (where different) of how the policy is modeled in the E*nhanced Ambition* scenario. The policies and actions included in this analysis are current as of July 2024. Policies and actions introduced or modified after July 2024 are not included in this analysis.

Table S2. Implementation of policy assumptions for the electricity sector in GCAM-USA-CGS

Type of Policy	Modeled Policy	***Current Policies*** **Scenario**	***Enhanced Ambition*** **Scenario**
Federal – IRA	Section 13101: PTC	Modeled as a $26/MWh subsidy for solar, wind, and geothermal technologies through 2024.[14] We assume that all projects pay prevailing wages. A 7.5% reduction in the credit value is assumed due to the transferability provision.	
	Section 13102: ITC extension	Modeled as a 30% subsidy for offshore wind and storage technologies through 2024.[14] We assume that all projects pay prevailing wages. A 7.5% reduction in the credit value is assumed due to the transferability provision.	
	Sections 13701 and 13702: New clean electricity PTC and ITC	Modeled in the same way as sections 13101 and 13102 through 2030, with phasedown after 2030.	In addition to the assumptions under *Current Policies*, the subsidies are extended through 2035.

<table>
<tr><th>Type of Policy</th><th>Modeled Policy</th><th>Current Policies Scenario</th><th>Enhanced Ambition Scenario</th></tr>
<tr><td rowspan="4">Federal – IRA</td><td>Section 13302: Residential clean energy credit</td><td colspan="2">Modeled by updating the rooftop ITC, which results in an additional 0.7GW/yr increase in electricity generation from rooftop solar photovoltaic (PV) on the lifetime of the credit through 2035.[14]</td></tr>
<tr><td>Section 13015: PTC for existing nuclear</td><td colspan="2">Modeled as a $15/MWh subsidy for nuclear technologies through 2030, with the simplifying assumption that all projects pay prevailing wages.[14] We also assume that these incentives, in combination with non-federal incentives and zero-emission credits, prevent the economic retirement of nuclear plants. As such, we model Georgia Vogtle units 3&4 coming online by 2025 and maintain existing nuclear capacity at today's levels.</td></tr>
<tr><td>Section 50144: Energy infrastructure reinvestment financing</td><td colspan="2">Modeled as $250 billion in loans and guarantees used to accelerate the retirement of coal-fired power generation and fund the construction of renewable electricity-generating capacity.[14] We estimate this to accelerate the retirement of 38 GW of additional coal-fired capacity beyond already scheduled retirements by 2030.</td></tr>
<tr><td>Section 13104 - 45Q: Extension of credits for captured CO_2</td><td colspan="2">Credits for CO_2 captured by projects that commence construction between 2023 and 2032 are applied to CCS technologies at a value of $51/ton.[14] These credits assume that half of projects meet prevailing wage and apprenticeship requirements, but do not assume that all projects meet these requirements and receive the full credit value available ($85/ton). CCS technology deployment endogenously responds to these subsidies.</td></tr>
<tr><td>Federal – Regulations</td><td>CAA section 111(b) and (d) Standards for New and Existing Stationary Combustion Turbines</td><td>Recently finalized standards under CAA section 111(b) and (d) for coal and new gas are modeled.

CAA section 111(b) requires at least 90% CCS for any new natural gas turbines with a capacity factor higher than 40% starting in 2032. This was modeled by assuming that all new baseload natural gas builds are equipped with CCS for the 2035 model period.

Under CAA section 111(d), long-term (operating after 2038) coal plants are required to be retrofitted with CCS (90% capture) by 2032. This was modeled by phasing down long-term coal capacity without CCS to zero between the 2030 and 2035 model periods and allowing for this to be replaced by coal with CCS capacity. We did not represent the emission rate limit (consistent with 40% gas cofiring) for existing coal plants that plan to operate past 2031 but retire before 2039, which our analysis anticipates will impact a small number of units.</td><td>We further assume that EPA strengthens regulations on gas plants and expands the regulations to cover existing gas power plants. These strengthened regulations would require CCS for plants whose annual capacity factor exceeds 20%. This is modeled by reducing generation from existing plants without CCS to levels consistent with a 20% annual capacity factor starting in 2035. In other words, we assume that all existing gas plants meet the standard by reducing their capacity factors rather than retrofitting with CCS.

We also assume that all new baseload and intermediate load natural gas power plants are equipped with CCS by 2030 (earlier than required by Current Policies). This reflects an expectation that investors will change their behavior in response to the strengthened standards described above.</td></tr>
</table>

Type of Policy	Modeled Policy	***Current Policies*** **Scenario**	***Enhanced Ambition*** **Scenario**
Non-federal	RPS	Current state-level RPS targets are modeled.	We assume that collectively, Tier 1 states achieve 75% renewable by 2035, Tier 2 states achieve 55%, and Tier 3 states achieve 20%. These shares are assumed to be achieved through a combination of strengthened RPS targets, permitting and siting reform, and other policy actions to increase renewable deployment.
	Cap and Trade	The Regional Greenhouse Gas Initiative (RGGI) is modeled as a 30% reduction in power sector emissions below 2020 levels by 2030 in participating states.[15]	
Coal phaseout		Not explicitly modeled in this scenario	Coal without CCS is phased out by 2030 due to a combination of market forces, state coal-exit policies, and regulatory compliance costs. This was modeled by setting a national constraint on coal power to reach zero by 2030, and by prohibiting the buildout of new coal plants in all states.

3.5. Transportation sector modeling assumptions

Table S3. Implementation of policy assumptions for the transportation sector in GCAM-USA-CGS

Type of Policy	Modeled Policy	***Current Policies*** **Scenario**	***Enhanced Ambition*** **Scenario**
Federal – IRA	Section 13401 - 30D: Clean vehicle credit	This tax credit has a maximum value of $7,500 with an EV being eligible for half of the credit if its battery meets domestic assembly requirements and the other half of the credit is contingent upon a specific share of the minerals used in the battery being sourced from North American or other free-trade countries.[14] We assume that the U.S. auto manufacturing sector will reorient itself so that all new EVs produced by 2030 will meet these requirements, and that by 2025, half of EVs sold will meet these requirements. If the car meets the battery assembly and mineral sourcing requirements, a consumer can receive the full value of the tax credit provided that their income does not exceed the income eligibility threshold and that the sales price of the car does not exceed manufacturer's suggested retail price (MSRP) eligibility thresholds. We find that 89% of Americans meet the income requirement and further assume that they would only purchase EVs that meet the MSRP threshold. Altogether, this yields an EV tax credit with an effective value of $6,673, implemented as a capital cost reduction. We assume that for the 2031-2035 model period that the tax credit takes on a value 40% of the 2030 value because it is scheduled to expire in 2032.	In addition to the assumptions under *Current Policies*, the tax credit is extended to be available at its full value through 2035.

Type of Policy	Modeled Policy	*Current Policies* Scenario	*Enhanced Ambition* Scenario
Federal – IRA	Section 13404: Alternative refueling property credit	This credit is assumed to be a $1,000 property credit available for LDV charging infrastructure for individuals in rural and low-income census tracts.[14] Based on census data, 17.4% of Americans live in counties that are either rural or low-income, so the $1,000 property credit is modeled as a national weighted average subsidy of $174 for capital infrastructure cost for EVs. We assume that for the 2031-2035 model period that the tax credit takes on a value 40% of the 2030 value because it is scheduled to expire in 2032.	In addition to the assumptions under *Current Policies*, the tax credit is extended to be available at its full value through 2035.
	Section 13403 - 45W: Commercial clean vehicle credit	This tax credit is modeled as a $40,000 capital cost reduction for electric heavy-duty freight trucks and a $7,500 capital cost reduction for electric medium-duty and light-duty freight trucks.[14] We assume that for the 2031-2035 model period, the tax credit takes on a value 40% of the 2030 value because it is scheduled to expire in 2032.	In addition to the assumptions under *Current Policies*, the tax credit is extended to be available at its full value through 2035.
	Sections 13201, 13202, and 13203: Extension of incentives for biofuels	Implemented as subsidies in 2025 for biodiesel, cellulosic ethanol, Fischer Tropsch (FT) biofuels, cellulosic ethanol with CCS, and FT biofuels with CCS.[14] We assume that jet fuel is the first market for FT biofuel, and FT biofuels therefore receive the aviation fuel credit.	In addition to the assumptions under *Current Policies,* the tax credit is extended to be available at its full value through 2035.
Federal – BIL	Section 11401 and 11403: Grants from charging and fueling infrastructure, Carbon reduction program, and National Electric Vehicle Formula Program	BIL's $10.7 billion investment in LDV EV charging infrastructure is implemented as an $802 reduction in per-vehicle charging infrastructure cost, based on modeled vehicle fleet size in GCAM-USA-CGS, for model periods 2025 and 2030.[16]	
	Section 11115 and 11403: Congestion mitigation and air quality improvement program, and Carbon reduction program	BIL's $4.24 billion investment in medium- and heavy-duty truck EV charging infrastructure is implemented as a $9,211 reduction in per-vehicle charging infrastructure cost, based on fleet size in GCAM-USA-CGS, for model periods 2025 and 2030.[16]	
	Sections 71101 and 30018: Clean school bus program and Grants for buses and bus facilities	BIL's $5 billion investment in school bus electrification is implemented as a $25,000 reduction in per-vehicle purchase cost for model periods 2025 and 2030. A $2.625 billion investment in transit bus electrification is implemented as a $29,167 reduction in per vehicle purchase cost for model periods 2025 and 2030.[16]	
Federal – Regulations	CAFE standards for LDVs	Federal internal combustion engine GHG performance standards are improved so that nationally, fuel efficiency reaches 143 gCO_2/mi for new passenger cars and 193 gCO_2/mi for new SUVs by 2030.[17] Note: these are based on the National Highway Traffic Safety Administration (NHTSA) minimum standard and are not inclusive of ZEVs. To reflect the latest rulemaking from the EPA, we ensure that ZEV sales shares for new LDVs fall within the estimated ranges for 2030 and beyond as presented in the new GHG standards for LDVs.[18]	

Type of Policy	**Modeled Policy**	***Current Policies* Scenario**	***Enhanced Ambition* Scenario**
Federal – Regulations	GHG emissions standards for freight trucks	Internal combustion engine GHG performance standards are modeled to reflect efficiency improvement rates existing GHG emissions standards for heavy-duty gasoline- and diesel-powered engines.[19]	Same as in the *Current Policies* scenario through 2025. Efficiency is assumed to improve further by 5% from 2026-2030 and again from 2031-2035.
Non-federal	LDV ZEV sales mandates and targets	California and the 14 other states that have adopted ZEV sales targets consistent with California's Advanced Clean Cars (ACC) II legislation are assumed to achieve their passenger car sales target of 68% electric in 2030 and 100% in 2035.[20] Additionally, the 2 states that have only adopted legislation consistent with California's ACC I legislation are modeled to have ZEV sales reach 22% in 2025.	Through a combination of widespread adoption of ZEV sales targets, market forces, and other policies to enhance EV deployment, Tier 1 states are assumed to achieve ZEV sales shares equivalent to targets set by California. Tier 2 and Tier 3 states are assumed to achieve these sales shares but on a delayed schedule, 3 years later (Tier 2 states) and 6 years later (Tier 3 states) than Tier 1 states.
	LDV ZEV incentives	Major existing incentives for LDV ZEVs at the state-, utility-, and district levels from the Alternative Fuels Data Center are modeled at the state level as reductions in per-vehicle capital cost. Altogether, these are equivalent to a national average capital cost reduction for LDV EVs of $826 per vehicle.	
	Low carbon fuel standards	Not explicitly modeled in this scenario	Tier 1 states are assumed to achieve a biofuels share of 20% in 2030 and 25% in 2035. This is based on the California Low Carbon Fuel Standard for liquid fuels consumed in the transportation sector.[21]
	Freight truck ZEV sales mandates and targets	California and 11 other states are assumed to achieve sales targets for electric trucks through 2035 consistent with California's ACT legislation.[22]	Through a combination of widespread adoption of ZEV sales targets, market forces, and other policies to enhance EV deployment, Tier 1 states are assumed to achieve ZEV sales shares equivalent to targets set by California. Tier 2 and Tier 3 states are also assumed to achieve these sales shares but on a delayed schedule, 3 years later (Tier 2 states) and 6 years later (Tier 3 states) than Tier 1 states.
	Bus ZEV incentives and sales targets	Not explicitly modeled in this scenario.	A combination of federal and non-federal investments and fleet procurement targets lead to 100% electrification of new bus sales in 2030. This was modeled by raising the national-level sales shares to reach 100% electric by 2030.
	Vehicle miles traveled (VMT) reductions	Not explicitly modeled in this scenario.	Federal investment, state and local planning lead to annual average per capita passenger transportation demand reductions ranging from 0.75% to 1.25% in all states from 2025-2035 (consistent with current ambition in Tier 1 states).[23,24] Annual average per capita VMT reductions were modeled as state-level service demand reduction rates for passenger mode transit.

3.6. Building sector modeling assumptions

Table S4. Implementation of policy assumptions for the buildings sector in GCAM-USA-CGS

Type of Policy	Modeled Policy	***Current Policies*** **Scenario**	***Enhanced Ambition*** **Scenario**
Federal – IRA	Section 13303: Energy efficient commercial building deduction	This provision is estimated to reduce commercial HVAC costs by 3%.[14] This was modeled as a 3% subsidy for new commercial high-efficiency heating and cooling technologies in 2025 and 2030.	In addition to the assumptions under *Current Policies*, the subsidies are extended through 2035.
	Sections 13301 - 25C and 13304 and 50121: Energy efficient home improvement credit, Energy efficient home credit, and Home energy efficiency credit	Modeled by improving shell efficiency in residential buildings based on the AEO 2022 "Alternative Policies – Extended Credit" case.[14,25]	
	Section 51022: High efficiency home rebate program	Modeled as a subsidy to high-efficiency technologies in residential buildings in 2025 and 2030. Two-thirds of consumers are assumed to be eligible for this credit, so this was implemented as a weighted average across all consumers with the effective value of the credit modeled to be 66% of each of the following: $1,750 to electric heat pump water heaters, $4,000 to electric heat pumps for space heating, $420 to electric ovens, $420 to electric heat pump clothes dryers, $1,600 for high-efficiency air conditioning.[14]	In addition to the assumptions under *Current Policies*, the subsidies are extended through 2035.
Non-federal	Energy efficiency standards (EERS)	Current state-level EERS were modeled by reducing state-level building service demands. However, the energy savings yielded are insignificant at the national level.	Heightened EERS and building codes were modeled by reducing state-level building service demands. Tier 1 and Tier 2 states reach 4% annual efficiency savings by 2030, in alignment with the goal endorsed by the U.S.[26]
	Zero-emission appliance standards	Not explicitly modeled in this scenario.	Zero-emission appliance standards were modeled by driving space heating and water heating sales to 100% electric by 2030 in Tier 1 states and 2035 in Tier 2 states.[27]
	Zero-emission construction standards	Not explicitly modeled in this scenario.	Zero-emission construction standards were modeled by assuming that Tier 1 and Tier 2 states begin implementing all new electric construction by 2035.

3.7. Industry and other sectors modeling assumptions

Table S5. Implementation of policy assumptions for industry and other sectors in GCAM-USA-CGS

Type of Policy	Modeled Policy	*Current Policies* Scenario	*Enhanced Ambition* Scenario
Federal - IRA	Section 13104 - 45Q: Extension of credits for captured CO_2	Credits for CO_2 captured by projects that commence construction between 2023 and 2032 are applied to relevant technologies at a value of $51/ton for CCS.[14] These credits assume that half of projects meet prevailing wage and apprenticeship requirements, but do not assume that all projects meet these requirements and receive the full credit value available ($85/ton). Existing credits for captured CO_2 at $85/ton are implemented as a subsidy for cement and ethanol CCS responds to these subsidies endogenously.	This subsidy is also assumed to result in sequestration levels from ethanol CCS consistent with Rhodium Group's analysis by 2035.[28] A small amount of CCS in the paper and pulp industry is modeled, well below the U.S. share of global potential identified in the literature.[29]
	Section 13204 - 45V: Production credit for clean hydrogen	Modeled as different subsidies to hydrogen technologies depending on their carbon intensities.[14] Fossil hydrogen without CCS is assumed to claim 45Q instead. 50% of projects are assumed to pay prevailing wages.	
	Section 13501 - 48C: Manufacturing investment tax credit for advanced energy projects	Designates $10 billion for industrial and manufacturing facilities aiming to equip themselves with technology to curtail GHG emissions.[14] This was modeled by specifying electrification rates aligned with an Energy Innovation analysis on low-temperature heating in the industrial sector.[30]	
	Section 50161 - Advanced industrial facilities deployment program	Designates $5.8 billion towards advanced industrial technology at energy-intensive industrial and manufacturing facilities.[14] This was assumed to result in faster equipment stock turnover for fossil fuels, modeled by shortening the average lifetime of existing industrial facilities.	In addition to the assumptions under *Current Policies,* we assume that new coal is not used as a fuel source in all industries.
	Section 60113: Methane emissions reduction program	This provision has a fee of $1,500/t$CH_4$ ($60/t$CO_2$e) on fugitive methane in the oil and gas sector on select facilities not in compliance with the EPA oil and gas methane regulations. We assume that compliance with the EPA oil and gas methane regulations results in a 63% reduction in upstream oil and gas methane emissions.[31] Upstream oil and gas methane emissions are adjusted based on estimated future oil and gas production levels. Downstream oil and gas methane emissions are adjusted according to changes in oil and gas consumption in this scenario. Coal mine methane emissions are adjusted according to changes in coal consumption in this scenario.	An economy-wide methane fee of $1,500/tCH4 ($60/tCO_2e) was modeled, using the EPA's marginal abatement cost (MAC) curves for methane.[32] State and federal incentives for agricultural methane emissions reductions deliver reductions equivalent to those achievable at $750/t$CH_4$ ($30/t$CO_2$e) in the EPA MAC curve for methane. Upstream oil and gas methane emissions are adjusted based on estimated future oil and gas production levels. Downstream oil and gas methane emissions are adjusted according to changes in oil and gas consumption in this scenario. Coal mine methane emissions are adjusted according to changes in coal consumption in this scenario. Organic waste diversion from landfills increases to 15% by 2030 and 30% by 2035.
Federal - Regulations	Standards on oil refining CCS	Not explicitly modeled in this scenario.	We assume that oil refineries install CCS capability for 50% of oil by 2035, resulting in sequestration consistent with the sequestration and cost existing in the literature.[33,34]

Type of Policy	Modeled Policy	*Current Policies* Scenario	*Enhanced Ambition* Scenario
Non-federal	Industry CCS targets	Not explicitly modeled in this scenario.	It is assumed that all states with cement production install CCS capability for 40% of cement produced by 2035, consistent with California's 40% goal.[35]
HFCs		National HFC phasedown is implemented consistent with the American Innovation and Manufacturing (AIM) Act, reducing emissions up to 52% below 2020 levels by 2035 (consistent with analysis and modeling results developed by California Air and Resources Board (CARB)).	National HFC phasedown is implemented consistent with the AIM Act. Tier 1 states achieve additional reductions through more comprehensive measures including Significant New Alternatives Policy (SNAP) and Refrigerant Management Programs (RMP) programs, reducing emissions up to 56% below 2020 levels by 2035 (consistent with analysis and modeling results developed by CARB).[1]
Land use, land-use change and forestry (LULUCF)		LULUCF emissions for CO_2 and N_2O are specified exogenously and adapted from *America Is All In*'s lands sector report.[36] *Current Policies* assumes full implementation of roughly $42 billion of current state and federal policies in agriculture and forestry practices, including BIL and IRA. This results in a natural carbon sink of 884 $MtCO_2e$. For CH_4 emissions assumptions, please see *Section 60113: Methane emissions reduction program above.*	LULUCF emissions for CO_2 and N_2O are specified exogenously and adapted from *America Is All In*'s lands sector report.[36] *Enhanced Ambition* assumes $160 billion in investments in climate-smart policies resulting from enhanced state-level action. This results in a natural carbon sink of 928 $MtCO_2e$ by 2035. For CH_4 emissions assumptions, please see *Section 60113: Methane emissions reduction program above.*
Economy-wide GHG targets		Not explicitly modeled in this scenario.	Tier 1 states are assumed to achieve their near- and long-term economy-wide GHG targets. Economy-wide GHG constraints were modeled for states that were more than 1 $MtCO_2e$ away from their target in 2035, including California, Washington, and New Jersey.
Direct air carbon capture and storage (DACCS)		Not explicitly modeled in this scenario.	DACCS is included as an additional mitigation option, resulting in 20 $MtCO_2$ of annual removals by 2035. This level of removal is consistent with announced DACCS facilities in the United States.[37]

[1] Emissions impacts from national and state-level HFC regulations were derived from a short-lived climate pollutant tool developed by CARB and extrapolated to additional states. We used the tool's Kigali phasedown scenario as a proxy for the impact of the AIM Act.

4. Emissions results

4.1. Emissions reduction by sector

In the *Current Policies* scenario, we find that economy-wide GHG emissions are reduced to 48% below 2005 levels by 2035 (see Table S6 for a sectoral breakdown of emissions reductions). Existing state-level RPS, CAFE standards, and several tax credits from the IRA for renewable electricity generation, zero-emissions vehicles (ZEVs), and carbon capture and storage (CCS) are among the key policy drivers in this scenario. In the *Enhanced Ambition* scenario, we find that a comprehensive society-wide climate strategy has the potential to deliver a 65% reduction by 2035. A sector-by-sector breakdown of the results for this scenario is shown in Table S6 alongside results from our *Current Policies* scenario. Some of the additional policy actions modeled in this scenario include a full phaseout of unabated coal-fired electricity generation by 2030, accelerated adoption of ZEV in light-duty vehicle, bus, and freight truck markets, ramped up electric appliance standards, more stringent standards and oil and gas methane, as well as extensions of the existing IRA tax credits beyond their legislated sunset dates.

Table S6. Emissions results by sector (Methane's AR5 100-year GWP of 28 is used in this table).

Sector/GHG	**Emissions 2005 ($MMTCO_2e$)**	**Emissions 2020 ($MMTCO_2e$)**	**Emissions 2035 ($MMTCO_2e$)**		**Change from 2005 to 2035 ($MMTCO_2e$)**		**Change relative to 2005 (%)**		**Contribution to total reductions relative to 2005 (%)**	
			Current Policies	***Enhanced Ambition***	***Current Policies***	***Enhanced Ambition***	***Current Policies***	***Enhanced Ambition***	***Current Policies***	***Enhanced Ambition***
Electricity CO_2	2,417	1,457	570	254	-1,847	-2,163	-76%	-89%	58%	50%
Transport CO_2	1,869	1,581	1,008	791	-861	-1,078	-46%	-58%	27%	25%
Industry CO_2	1,193	1,106	1,109	863	-84	-330	-7%	-28%	3%	8%
Buildings CO_2	586	542	465	330	-121	-255	-21%	-44%	4%	6%
Other CO_2	67	32	27	21	-43	-48	-60%	-68%	1%	1%
CH_4	852	807	684	522	-169	-330	-20%	-39%	5%	8%
N_2O	427	400	409	402	-18	-25	-4%	-6%	1%	1%
F-Gases	138	180	103	93	-36	-45	-26%	-33%	1%	1%
Direct Air Capture	0	0	0	-20	0	-20	0	N/A	0%	1%
Land sink	-854	-853	-884	-928	-31	-75	4%	9%	1%	2%
Net GHG Total	**6,697**	**5,252**	**3,490**	**2,329**	**3,206**	**4,368**	**48%**	**65%**	**100%**	**100%**

4.2. Calibrating to EPA inventory

For both scenarios, we calibrated emission results through the year 2020 to historical GHG emissions from the 1990-2021 EPA inventory report.[38] 2020 is a model year in GCAM-USA-CGS, which operates in 5-year time steps. However, we note that net GHG emissions from the 1990-2021 EPA inventory report increased by 6.4% between 2020 and 2021, so the reductions needed relative to 2021 will be somewhat higher than reductions relative to 2020, which is the base year used in the paper.

4.3. Comparison with other studies

Recent studies have also examined GHG reductions in 2035 (Figure S2). Princeton ZERO's Net-Zero Pathway Scenario reflects a cost-effective pathway to reduce U.S. GHG emissions from 2023 levels to net-zero by 2050, finding that the U.S. could achieve a 60% reduction by 2035 under this pathway.[39] Energy Innovation's "Continued Climate Leadership" scenario includes sectoral policies to achieve U.S. 2030 NDC and net-zero emissions by 2050, finding a 70% reduction by 2035.[40] Our *Enhanced Ambition* scenario lands in the middle of these numbers at 65% emissions reductions.

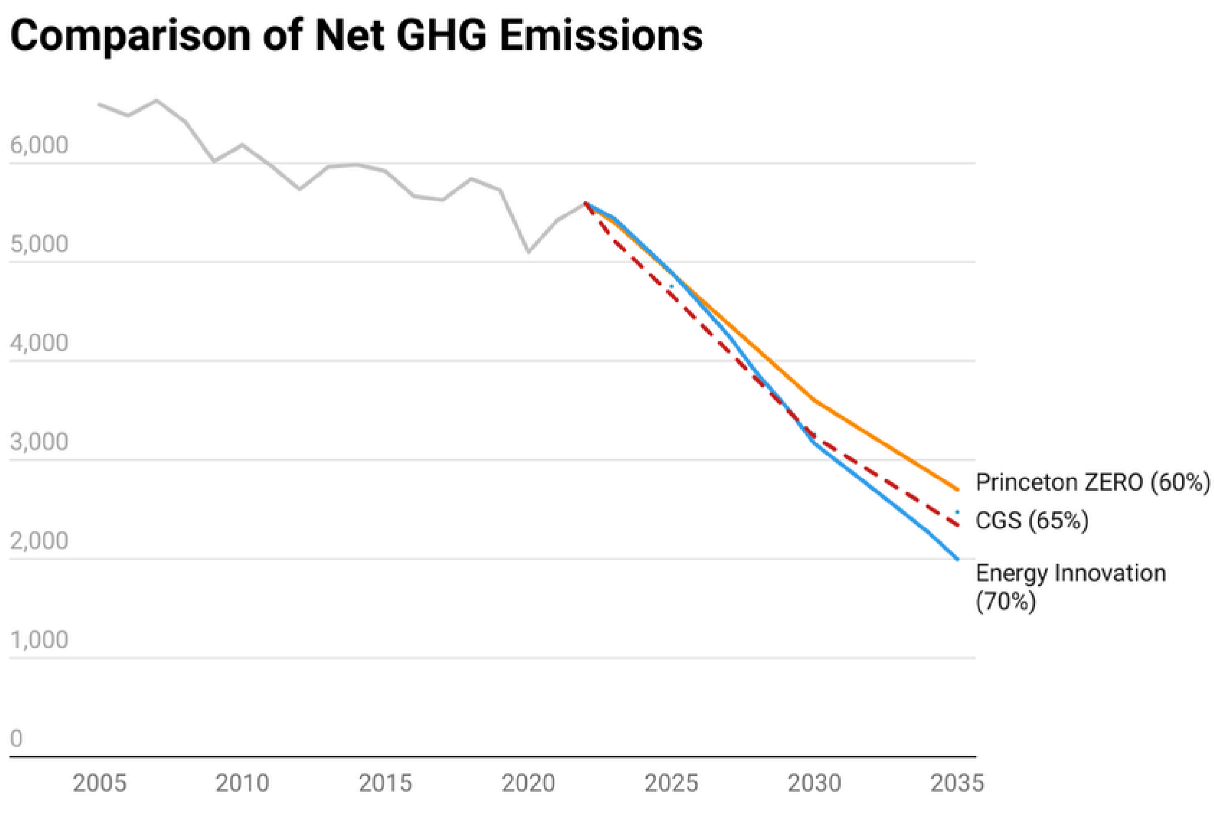

Figure S2. Net GHG emissions under high-ambition scenarios across teams. Historical data from the EPA is used through 2022.

Additionally, Princeton ZERO, Energy Innovation, and Rhodium Group have estimated the impacts of existing policies.[39-41] Across teams, current policies are expected to deliver 40-46% emissions reductions by 2035 in their central cases, compared to our *Current Policies* scenario at 48%.

5. Sensitivity analysis

5.1 Core assumptions

We assessed emissions projections from the two scenarios by varying assumptions on a few important drivers, including GDP, population growth, oil and gas prices, solar and wind costs, and the land sink carbon sequestration potential. See Table S8 for our sensitivity assumptions, and Section 3.4 for the sources for our core assumptions.

Table S8. Assumptions under sensitivity scenarios

Driver	Core Assumptions	Sensitivities
GDP	GDP is assumed to grow by 1.68% per year on average from 2022 through 2035.	**High**: GDP is assumed to grow by 2.12% per year on average through 2035. **Low**: GDP grows by 1.08% per year on average through 2035.
Population	Population is assumed to grow by 0.46% per year on average from 2022 through 2035.	**High**: Grows by 0.66% per year on average through 2035. **Low**: Grows by 0.34% per year on average through 2035.
Fuel prices	Gas prices are assumed to increase at an average rate of 1.3% per year from 2021 through 2035.	**High**: Gas prices are assumed to increase at an average rate of 4.3% per year from 2021 through 2035. **Low**: Gas prices are assumed to decrease at an average rate of 0.01% per year from 2021 through 2035.
	Oil prices are assumed to increase at an average rate of 2.5% per year between 2021 and 2035.	**High**: Oil prices are assumed to increase at an average rate of 8.4% per year from 2021 through 2035. **Low**: Oil prices are assumed to decrease at an average rate of 0.3% per year from 2021 through 2035.
Solar power	Utility solar PV capital costs are assumed to decrease by 35% from 2022 to 2035.	**High**: Utility solar PV capital costs are assumed to decrease by 47% from 2022 to 2035. **Low**: Utility solar PV capital costs are assumed to decrease by 10% from 2021 to 2035.
Wind power	Land-based wind and offshore wind capital costs are assumed to decrease by 34% and 20%, respectively, from 2022 to 2035.	**High**: Land-based wind and offshore wind capital costs are assumed to decrease by 50% and 23%, respectively, from 2022 to 2035. **Low**: Land-based wind and offshore wind capital costs are assumed to decrease by 29% and 13%, respectively, from 2022 to 2035.
LULUCF	LULUCF sector is assumed to sequester 928 MtCO_2 and 884 MtCO_2 by 2035 under *Enhanced Ambition* and *Current Policies*, respectively.	**High**: LULUCF sector is assumed to sequester 943 MtCO_2 sequestration by 2035. **Low**: LULUCF sector is assumed to sequester 762 MtCO_2 sequestration by 2035.

5.2 100% clean electricity

In addition to the variation of core model assumptions in the *Current Policies* and *Enhanced Ambition* scenarios, we explored an alternative scenario in which the U.S. electricity grid is 100% powered by clean technologies by 2035. As we were not able to model specific policies that would achieve this target, we placed a constraint on the model to achieve a 100% clean generation mix by 2035. In this scenario, unabated gas is phased down and replaced by renewables (Figure S3). Overall electricity demand also falls due to cross-sectoral interactions with fuel prices.

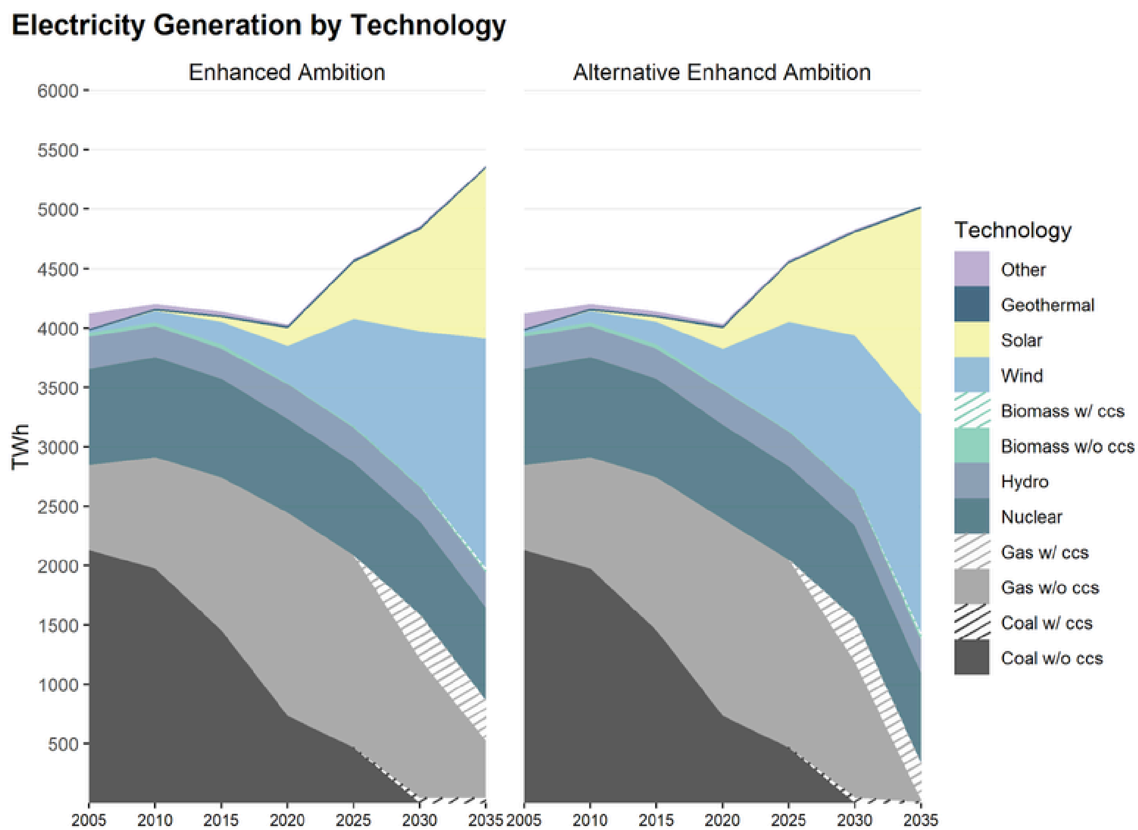

Figure S3. Electricity generation through 2035 under the core *Enhanced Ambition* scenario, which achieves a 91% clean generation mix by 2035, and an alternative *Enhanced Ambition* scenario that achieves a 100% clean generation mix by 2035. Under the alternative scenario, unabated gas is phased down by 2035 and replaced largely by renewables.

6. BIBLIOGRAPHY

1. Bond-Lamberty, B. *et al.* GCAM 6.0. Joint Global Change Research Institute https://doi.org/10.5281/ZENODO.6619287 (2022).
2. National Renewable Energy Laboratory. 2022 Annual Technology Baseline. https://atb.nrel.gov/electricity/2022/index (2022).
3. US Environmental Protection Agency. Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation Potential: 2015-2050. https://www.epa.gov/global-mitigation-non-co2-greenhouse-gases/global-non-co2-greenhouse-gas-emission-projections (2019).
4. Hultman, N. *et al. Accelerating America's Pledge: Technical Appendix. The America's Pledge Initiative on Climate Change.* 62 (2019).
5. Hultman, N. E. *et al.* Fusing subnational with national climate action is central to decarbonization: the case of the United States. *Nat. Commun.* 11*, 5255 (2020).*
6. Kennedy, K. *et al*. *Blueprint 2030: An All-In Climate Strategy for Faster, More Durable Emissions Reductions.* https://www.americaisallin.com/blueprint-2030 (2022).
7. Hultman, N. *et al*. *An All-In Climate Strategy Can Cut U.S. Emissions by 50% by 2030.* https://cgs.umd.edu/research-impact/publications/all-climate-strategy-can-cut-us-emissions-50-2030 (2021).
8. Zhao, A. et al. *An "All-In" Pathway To 2030: U.S. Methane Emissions Reduction Potential.* https://cgs.umd.edu/research-impact/publications/all-pathway-2030-us-methane-emissions-reduction-potential (2022).
9. Zhao, A. et al. *An All-In Pathway to 2030: The Beyond 50 Scenario*. https://www.americaisallin.com/Beyond50 (2022).
10. Zhao, A. *et al.* High-ambition climate action in all sectors can achieve a 65% greenhouse gas emissions reduction in the United States by 2035. *Npj Clim. Action* 3, 1–11 (2024).
11. Annual Energy Outlook 2023 - U.S. Energy Information Administration (EIA). https://www.eia.gov/outlooks/aeo/index.php.
12. Larsen, K. *et al. Taking Stock 2020: The COVID-19 Edition. 18 https://rhg.com/research/taking-stock-2020/ (2020).*
13. National Renewable Energy Laboratory (NREL). 2023 Annual Technology Baseline (ATB) Cost and Performance Data for Electricity Generation Technologies. (2023).
14. *Inflation Reduction Act of 2022.* H.R.5376.
15. The Regional Greenhouse Gas Initiative (RGGI). https://www.rggi.org/.
16. Federal Transit Administration. Bipartisan Infrastructure Law. *US Department of Transportation* https://www.transit.dot.gov/BIL (2023).
17. US Department of Transportation. Corporate Average Fuel Economy. nhtsa.gov https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy.
18. US Environmental Protection Agency. Regulations for Greenhouse Gas Emissions from Passenger Cars and Trucks. https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-passenger-cars-and (2022).
19. US EPA. Final Rule and Related Materials for Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards. https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-and-related-materials-control-air-pollution (2022).
20. California Air Resources Board. Advanced Clean Cars II. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii.
21. California Air Resources Board. Low Carbon Fuel Standard. *California Air Resources Board* https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard.
22. California Air Resources Board. Advanced Clean Trucks Fact Sheet. https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-trucks-fact-sheet (2021).
23. *Statewide Multimodal Transportation Plan.* https://www.minnesotago.org/application/files/4216/7165/1126/2022_SMTP_ExecutiveSummary_12202022.pdf (2022).
24. California Air Resources Board. 2022 Scoping Plan for Achieving Carbon Neutrality. (2022).
25. US Energy Information Administration. Annual Energy Outlook 2023. https://www.eia.gov/outlooks/aeo/tables_ref.php (2023).
26. International Energy Agency. At IEA conference, 46 governments endorse goal of doubling global energy efficiency progress by 2030. IEA https://www.iea.org/news/at-iea-conference-46-governments-endorse-goal-of-doubling-global-energy-efficiency-progress-by-2030 (2023).
27. Bay Area Air Quality Management District. Air District strengthens building appliance rules to reduce harmful NOx emissions, protect air quality and public health. *Bay Area Air Quality Management District* https://www.baaqmd.gov/news-and-events/page-resources/2023-news/031523-ba-rules (2023).

28. Larsen, J., King, B., Hiltbrand, G. & Jones, W. Capturing the Moment: Carbon Capture in the American Jobs Plan. *Rhodium Group* https://rhg.com/research/carbon-capture-american-jobs-plan/ (2021).
29. Kuparinen, K., Vakkilainen, E. & Tynjälä, T. Biomass-based carbon capture and utilization in kraft pulp mills. *Mitig. Adapt. Strateg. Glob. Change* 24, 1213–1230 (2019).
30. Rissman, J. *Decarbonizing Low-Temperature Industrial Heat in the U.S.* https://energyinnovation.org/wp-content/uploads/2022/10/Decarbonizing-Low-Temperature-Industrial-Heat-In-The-U.S.-Report-1.pdf (2022).
31. US Environmental Protection Agency. EPA's Final Rule for Oil and Natural Gas Operations Will Sharply Reduce Methane and Other Harmful Pollution. *Controlling Air Pollution from the Oil and Natural Gas Operations* https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-operations/epas-final-rule-oil-and-natural-gas (2023).
32. US Environmental Protection Agency. U.S. State-level Non-CO2 GHG Mitigation Report. *Global Mitigation of Non-CO2 Greenhouse Gases* https://www.epa.gov/global-mitigation-non-co2-greenhouse-gases/us-state-level-non-co2-ghg-mitigation-report (2022).
33. Cresko, J. *et al. U.S. Department of Energy's Industrial Decarbonization Roadmap.* DOE/EE--2635, 1961393 https://www.osti.gov/servlets/purl/1961393/ (2022) doi:10.2172/1961393.
34. King, B., Gaffney, M., Bower, G. & Pastorek, N. *Expanding the Industrial Decarbonization Toolkit.* https://rhg.com/research/expanding-the-industrial-decarbonization-toolkit/ (2024).
35. Josh Becker. *Greenhouse Gases: Cement Sector: Net-Zero Emissions Strategy.* SB-596.
36. Kennedy, S. *et al. Harnessing the Land Sector to Achieve U.S. Climate Goals: An All-of-Society Approach to Meeting Our Climate Goals and Bolstering the Carbon Sink by 2035.* https://cgs.umd.edu/sites/default/files/2024-01/file_All-In%20Lands%20Report_Final.pdf (2024).
37. Guel, T. *et al. Direct Air Capture: A Key Technology for Net Zero.* https://iea.blob.core.windows.net/assets/78633715-15c0-44e1-81df-41123c556d57/DirectAirCapture_Akeytechnologyfornetzero.pdf (2022).
38. US Environmental Protection Agency. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021. *Greenhouse Gas Emissions* https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021 (2023).
39. Jenkins, J. D., Farbes, J. & Jones, R. Climate Progress 2024: REPEAT Project's Annual U.S. Emissions Pathways Update. (2024) doi:10.5281/zenodo.13345138.
40. Mahajan, M., Orvis, R., Gopal, A., O'Brien, D. & Goldstein, R. *The Second half of the decisive decade.* (2024).
41. King, B. et al. *Taking Stock 2024: US Energy and Emissions Outlook*. https://rhg.com/research/taking-stock-2024/ (2024).