ACCELERATING AMERICA'S PLEDGE

GOING ALL-IN TO BUILD A PROSPEROUS, LOW-CARBON ECONOMY FOR THE UNITED STATES

Technical Appendix

Table of Contents

Introduction

In 2017, Michael Bloomberg and Jerry Brown launched the America's Pledge initiative, a new initiative to analyze, aggregate, and showcase actions by U.S. states, cities, and businesses to drive down their greenhouse gas (GHG) emissions consistent with the goals of the Paris Agreement. In 2017, the first America's Pledge report was released. It emphasized the importance of contributions from states, cities, and businesses to achieving our national climate goals. In 2018, the second report, *Fulfilling America's Pledge*, delivered a robust analysis of current and potential future climate commitments and actions by states, cities, and businesses in the United States. It modeled the extent to which states, cities, and businesses could keep the U.S. on a trajectory toward deep decarbonization.

The new 2019 report, *Accelerating America's Pledge*, is the third major report from America's Pledge. It builds on our previous analyses to assess new commitments from states, cities, tribes, counties, businesses, investors, regional associations, faith-based groups, cultural institutions, universities, citizen groups, and others, collectively referred to throughout the report as states, cities, and businesses; tracks progress towards a U.S. deep decarbonization strategy; and lays out a comprehensive American climate action strategy, which includes an 'All-In' federal re-engagement platform. Understanding the implications of state, city, and business actions requires grappling with a myriad of possible actions that can overlap and interact with one another in a multitude of ways. America's Pledge combines tools and analytical strategies to take on this challenge. This technical appendix provides detailed information on the methodology used in *Accelerating America's Pledge*.

The best practice methods for collecting, aggregating, and modeling the collective impact of states, cities, and businesses on national emissions trajectories are evolving quickly. Because the cycle of ambition in the Paris Agreement is based on the ability of all actors – countries, states, cities, and businesses – to understand and scope ambitious action, these evolving analytical methods are of great relevance to a broad international community of actors. As this community looks to better understand how to scope and increase ambition ahead of 2020, America's Pledge can be an example of how to undertake a comprehensive and robust analysis that incorporates state, city, and business actions. This report is focused on 2030 given the international significance of 2030 in the Paris Agreement process and as many countries work to enhance their nationally determined contributions (NDCs).

Overview of Analytical Approach

INTRODUCTION TO THE ANALYTICAL APPROACH

The analysis in *Accelerating America's Pledge* followed the same analytical approach as the 2018 report. The approach consisted of three main steps: the study team (1) tallied and updated the scope and scale of individual climate commitments; (2) aggregated the impact of those commitments along with potential additional actions by states, cities, businesses, and federal actors at the sector level; and (3) projected the impact of those commitments and additional actions on economy-wide GHG emissions. The study team applied this strategy to understand the emissions implications of three distinct scenarios:

- A **Current Measures** scenario that projects where the U.S. is headed given current binding policies on the part of states, cities, and businesses. In addition to on-the-books policies, this scenario assumes technological and economic factors continue to shift from the present day.
- A **Bottom-Up** scenario that assumes a broad expansion of cutting-edge climate policies on the part of states, cities, and businesses
- An **All-In** scenario that includes a comprehensive American climate strategy integrating aggressive bottom-up action with renewed federal engagement after 2020.

The remainder of this section provides an overview of the analytical methodology to assess these three scenarios. An initial step in the modeling of each scenario was the sectoral analysis (described in detail in the *Assessing the Impact of Current Policies and Commitments* section). For the sectoral analysis, impacts of climate policies were measured in terms of activity data corresponding to a particular type of climate action (for example, TWh of renewable energy generation resulting from state and city policies and targets). To understand the combined effects of different actions while more explicitly considering their interactions within each sector and avoiding double counting, we used the Aggregation Tool for modeling Historic and Enhanced Non-federal Actions (ATHENA). ATHENA was specifically constructed for the analysis in the 2018 report and updated for the 2019 report.

The other key step in the analysis of the scenarios was economy-wide analysis (described in detail in the *Estimating Overall National GHG Implications Using Scenarios in GCAM-USA section*). For the economy-wide analysis, we estimated GHG emissions impacts using the U.S.-specific version of GCAM (GCAM-USA). GCAM-USA is a version of the GCAM integrated assessment model with greater detail for the United States. Information and preliminary estimates from the sectoral analysis served as inputs to the assessment of economy-wide impacts using GCAM-USA.

A core feature of this two-step analytical approach is the interaction between the sectoral and economy-wide components. Information from GCAM-USA served as an initial representation of key activity levels for the sectoral analysis using ATHENA, such as electricity demand and generation, vehicle sales and vehicle miles traveled, and growth forecasts. This information was then processed and adjusted in ATHENA to represent the impacts within each sector of

Figure 1 | **Three Step Analytical Methodology for Bottom-Up and All-In Scenarios**

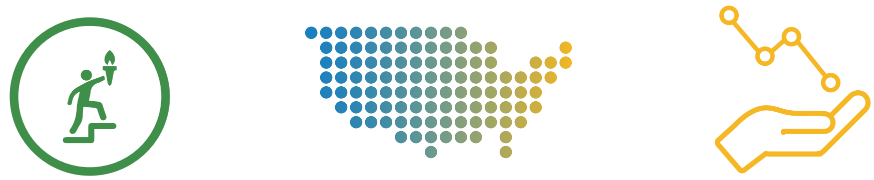
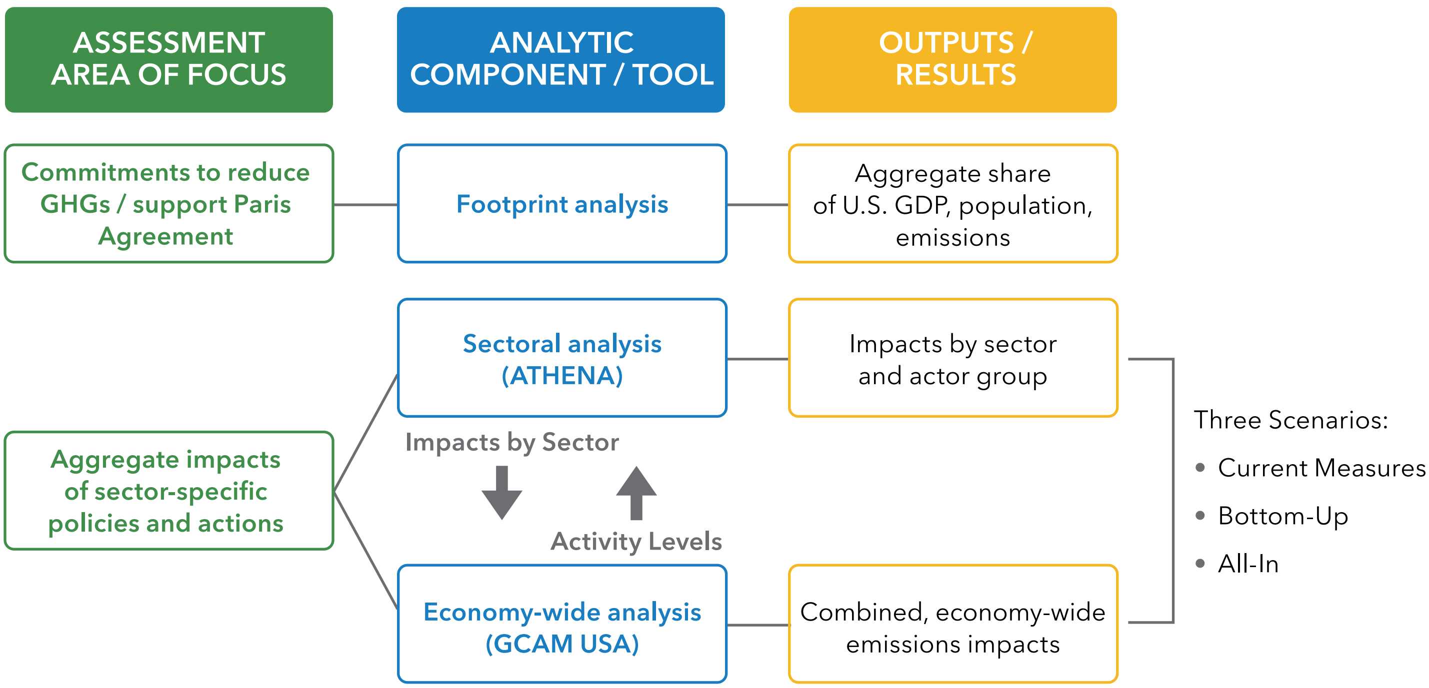


Figure 2 | **Analytical Strategy for America's Pledge 2019 Report**



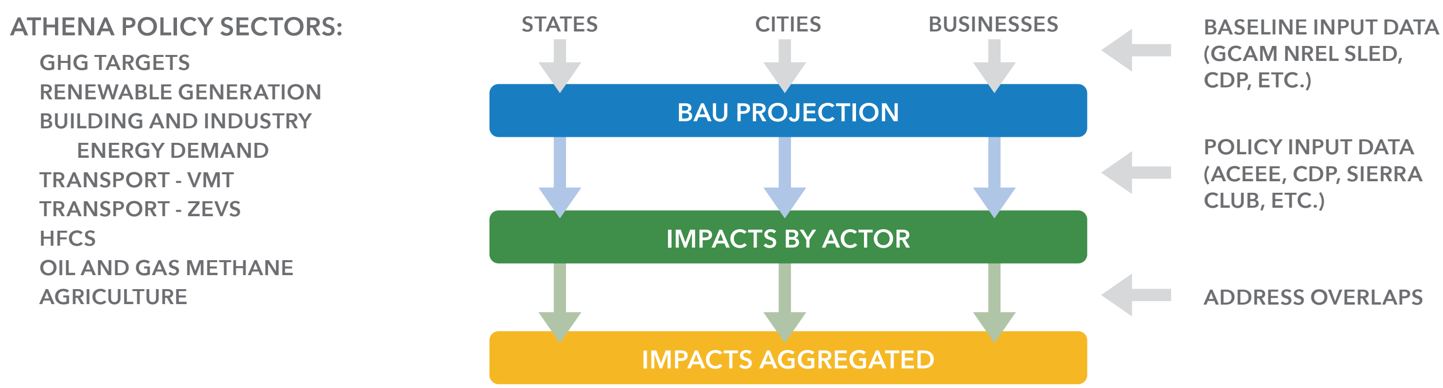
state, city, and business commitments from one scenario to the next. These impacts were then converted into sector-appropriate metrics at the state or regional level that were incorporated into the economy-wide analysis using GCAM-USA. Several iterations of this loop were conducted to take advantage of new insights and information that emerged in each step, so that the final scenario results are the outcome of this combined process. This interactive approach provides consistent characterization of sectoral and national emissions trajectories based on varying levels of real state, city, and business ambition.

A parallel step in the analytical process is a "footprint analysis", which estimates the scale of current coalitions of state, city, and business actors, as measured in terms of their share of national economic activity, population, and current GHG emissions. This component of the research largely focused on providing an update to similar footprint analyses from the 2017 and 2018 reports on the scale and scope of actions by states, cities, and businesses supporting the Paris Agreement. We compiled information on actors supporting the Paris Agreement, identified the number of states, cities, businesses, and universities with GHG reduction targets, and described the footprint of these actors in terms of population, economic activity, and current emissions. The methodology for the footprint analysis is described in more detail in Appendix B.

OVERVIEW OF ATHENA

When aggregating the impact of the climate actions that states, cities, and businesses are taking, we face an inherent nesting and "additionality" challenge. Businesses may be taking actions in cities that have their own suites of policies. City and business actions are, in turn, taking place in states with policies that may have overlapping goals. When modeling the impact of policies and commitments, it was necessary to control for this overlap. To overcome this, WRI developed a series of sector-specific, bottom-up models, referred to as ATHENA (Figure 3). ATHENA integrates state, city and business actions and aggregates their net contribution at the sector level.

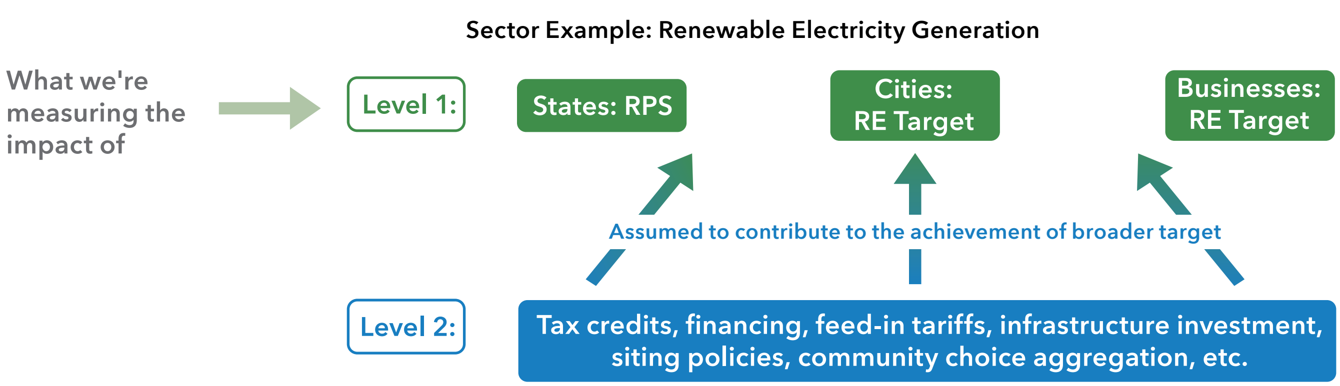
Figure 3 | ATHENA Modeling Flow



CAPTURING THE IMPACT OF NESTED POLICIES

A key issue in aggregating subnational actions is how to feasibly estimate the impact of nested policies that may be overlapping or reinforcing in terms of impact. For example, a state may have a renewable energy target that is described in terms of a percentage of total generation to be provided by renewable sources. The state may also have a set of more granular policies or approaches that directly or indirectly contribute to achieving the target, such as tax credits, feed-in tariffs, infrastructure investment, or community choice aggregation legislation, to name a few. For this analysis, we categorized climate policies and actions into "policy levels" as an organizing priniciple for the purpose of modeling impact. We defined Level 1 policies as those typically characterized by top-down targets such as a renewable electricity target for an entire state or city jurisdiction. We defined Level 2 policies as more granular measures contributing to the achievement of Level 1 policies (Figure 4). Our general approach was to estimate the impact of Level 1 policies rather than the Level 2 policies.

Figure 4 | Level 1 and Level 2 Policies

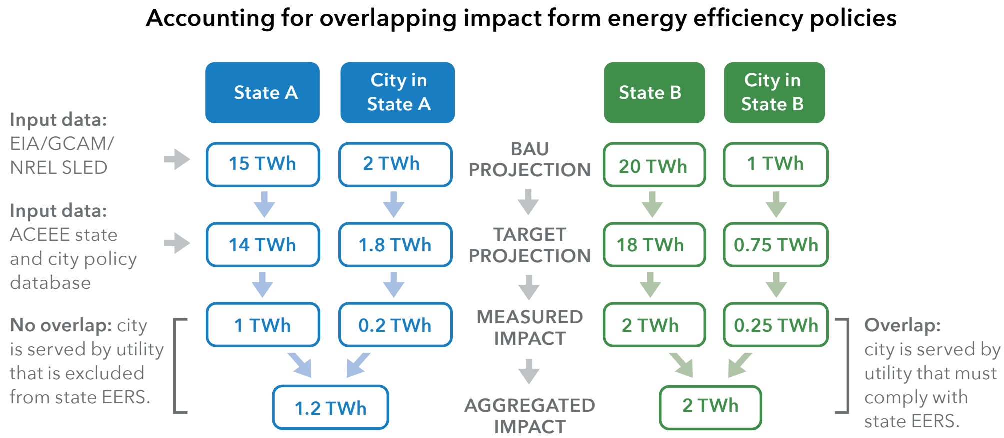


While top-down targets may often subsume more granular policies, this is not always the case. For example, significant infrastructure investment or pro-wind and pro-solar siting policies may occur within regions or communities without an on-the-books renewable electricity mandate and may nonetheless lead to increased renewable generation. Therefore, a limitation of our approach is that it does not capture the full impact of all possible actions. As the field of subnational policy modeling continues to develop, future analyses may build off of this approach and more explicitly model the full range of possible action. However, particularly when modeling impacts across multiple sectors of the economy, the inclusion of more granular, "lower-level" policies along with top-down targets can become exceedingly complex. Determinations of depth and breadth of the actions to be covered in the analysis ultimately depend on data and resource availability, the intended audience, and scope of work.

Addressing Overlap across Different Actor Levels

As previously mentioned, an additional challenge in aggregating actions by cities, states, and businesses is that policies at the state, city, and business level overlap within a given action area. In this analysis, we first estimated the full impact of a given policy or action by each type of actor. We then aggregated the impact of these different actions at the state level. It is in this aggregation step that we accounted for overlaps between actions within a sector and factored out double counting where actions contributed to the same policy goal. This two-step approach allows for flexibility in terms of attribution, so that the raw impact of actions at a given level (e.g., cities) can be assessed, but the overall estimates control for double counting. Assumptions regarding overlap vary by sector (see the Assessing the Impact of Current Policies and Commitments section).

Figure 5 | **Accounting for Overlap Across Actor Levels for Energy Efficiency Policies**



Source: ATHENA_EE

As an example of our approach, we consider energy efficiency (EE) targets implemented at the state level as well as by cities within the state, as shown in Figure 5. Two states (State A and State B) have energy efficiency targets that would result in 1 TWh and 2 TWh of energy savings, respectively. At least two cities in these states also have their own energy savings goals. For the city in state A, the city's utility is excluded from compliance toward the state's policy, and thus no overlap is assumed. The resulting aggregate figure adds together both the city and state level impacts. In state B, however, the city resides within a utility territory that must comply with the state goal, and overlap is therefore assumed to occur. In this case, we view the city's impact as contributing to the state's, and the aggregate total is equal to the state total. This example represents a simplified version of the approach and does not apply to all sectors included in ATHENA. More details on the aggregation methodologies employed, by sector, can be found in the sections that follow.

The majority of overlap assumptions included in ATHENA deal with the relationship between state- and city-level actions. While several corporate-level actions were included in our scoping analysis, only a select few were aggregated with state and city impacts and modeled in ATHENA. This approach results in part from a lack of reliable data on corporate actors to develop a meaningful methodology to account for overlap across all three levels of action (i.e. states, cities, and businesses). For many types of corporate action, available information does not specify the location (e.g., facility) where action was taken, making it difficult to include in a subnational aggregation analysis such as this. (Details on which actors and actions were included in each scenario are included *Sectoral Analysis* section.)

Interactions with GCAM-USA

ATHENA interacted with GCAM-USA in two primary ways: (1) by taking in baseline data from GCAM-USA as a reference case against which policy impacts are applied and (2) by converting these policy impacts back into metrics that could be integrated into GCAM-USA for economy-wide analysis of the scenarios.

Initial data from GCAM-USA was generally interpreted in ATHENA as a no-policy, reference scenario in which subnational policies, and some key federal policies, are not represented. Thus, the full impact of policies was applied to the baseline projections without need to address overlap. Exceptions to this assumption and cases where any subnational policies were already embedded in the baseline are discussed by sector below. (Further details on GCAM-specific assumptions can also be found in the *Estimating Overall National GHG Implications Using Scenarios in GCAM-USA* section.)

The GCAM-USA reference case scenario does include certain federal-level policies that have significant impacts within the sectors modeled. These include the federal production tax credit (PTC) and investment tax credit (ITC) in the renewable energy sector and federal fuel economy standards in the transportation sector. While sectoral modeling results in ATHENA typically represent the impact of state, city, or business policies only, final modeling results from GCAM-USA account for the combined impacts of these federal-level policies and the non-federal impacts from ATHENA. (More details on how these policies are integrated can be found in the *Estimating Overall National GHG Implications Using Scenarios in GCAM-USA* section.)

In addition, two types of federal policies not already included in GCAM-USA were explicitly modeled in ATHENA and aggregated with non-federal actions before being passed back to GCAM -USA as inputs. These were the U.S. Environmental Protection Agency (EPA) Section 608 refrigerant management policy for HFCs and regulations to reduce fugitive emissions in the oil and gas sector. (Further details on how these policies were incorporated into the analysis can be found in the sections on HFCs and oil and gas methane below.)

Estimating Increased Ambition

ATHENA was developed largely as a tool to quantify the impact of current policies and actions on the part of subnational actors. However, a key feature of the analysis presented in *Accelerating America's Pledge* is the presentation of not just the impact of current actions but also the potential impact of increased ambition envisioned in the Bottom-Up and All-In scenarios. Establishing these scenarios in ATHENA typically involved relying on the Current Measures impacts as a baseline, with impacts in each of the increased ambition scenarios being additive to those of the preceding scenario. However, there were some exceptions where assumptions were developed in a more top-down fashion or the sector was not explicitly modeled in the Current Measures scenario. These include assumptions regarding building electrification, medium- and heavy-duty vehicle electrification, and constraints on future gas builds, among others. The modeling of impacts in these sectors did not involve a bottom-up accounting of policy impacts in ATHENA. They we assessed outside of ATHENA and then fed into the economy-wide modeling. (Specific assumptions for all sectors included in the analysis are described in more detail in the *Detailed Summary Tables for Sectors and Scenarios* section.)

Sectoral Analysis

A key step in the analysis was the development of estimates of the sectoral implications of climate actions included in this study. We conducted an analysis of current policies and commitments (categorized as either "existing" or "pledged" measures) as well as the potential for accelerated and expanded ambition in the Bottom-Up and All-In scenarios. This section discusses the process of developing these estimates and their underlying assumptions in *Assessing the Impact of Current Policies and Commitments* and *Inputs and Assumptions for Bottom-Up and All-In Scenarios.* Note the term "sectors" as used in this section is meant to indicate policy areas in which state, city, and business impacts are explicitly modeled, such as renewable energy generation, vehicle miles traveled (VMT) reduction, or building and energy efficiency. The sectors described therefore do not necessarily correspond to traditional end-use sectors of the economy, but rather types of policy interventions included in the *Accelerating America's Pledge* report.

ASSESSING THE IMPACT OF CURRENT POLICIES AND COMMITMENTS

Overview of Approach

The following sections detail the process for modeling current policies and commitments and then provide an in-depth summary of how impacts were measured and aggregated. This aggregation process differs across the policy types based on the specific details about how state, city, and business climate actions interact for that policy type. Many, although not all, policies and actions described below were included in the Current Measures scenario.

Identifying Current Policies and Targets

Our approach to identifying and then quantifying the impact of subnational actions was informed by existing protocols and methodologies such as the Non-State and Non-Federal Action Guidance developed through the Initiative for Climate Action Transparency[1], the Global Covenant of Mayors Emission Scenario methodology,[2] and the Greenhouse Gas Protocol Mitigation Goal Standard and Policy and Action Standard[3].

Overall, our identification and aggregation process can be summarized as follows:

1. Surveyed at a minimum all 50 states, the 285 most populous cities in the U.S. (i.e., those with a population over 100,000), and any businesses that report relevant target information and/or activity data publicly. For some sectors, additional cities were included due to the availability of relevant data,
2. Identified subset of actions for inclusion in analysis (see the preceding section on capturing the impact of nested policies),
3. Collected necessary data to quantify each action (e.g. target information, historical data, reference case scenario projections),
4. Placed each action into the applicable category of existing or pledged (see the following section on existing and pledged actions),
5. Estimated a reference, "no policy" scenario for each sector through 2030, taking into account the effect of any embedded policies in the projections,
6. Calculated combined impacts for each actor level, and
7. Aggregated the impact across actor levels within each sector, taking into account overlapping impact.

Existing Actions vs. Pledged Actions

Current state, city, and business actions differ in terms of concreteness and stringency, ranging from clearly defined, legally binding actions that are already in force to aspirational actions not currently enacted, but which would have significant impact if achieved. This poses a challenge in the definition of the Current Measures scenario. To address these differences, actions are categorized in ATHENA as one of two types:

1. **Existing actions**: Actions that have been formally adopted by local and regional governments, are legally binding, and which are currently being implemented. These include legislation adopted in statehouses.
2. **Pledged actions**: Actions that represent clearly defined intentions on the part of states, cities, or businesses, but which are not legally binding and may lack transparency on progress toward implementation to date. These may include executive orders, mayoral announcements, or voluntary corporate commitments.

Table 1 to the right provides examples of various types of policies and the categories they fall under in ATHENA. Examples given are illustrative only, and descriptions by sector of how actions were categorized can be found in the remainder of this section.

These two categories allow for flexibility from a modeling standpoint. The scale of actions and their projected impact can be assessed through dual lenses (e.g., legally binding actions only or combined with pledged goals). However, the categories are not meant to indicate any type of judgement on the part of the authors on the likelihood of certain policies being implemented vis a vis others.

It is important to note that modeling results presented in the *Accelerating America's Pledge* report for the Current Measures scenario include only existing policies. Pledged actions, while also described in this section, are only included in higher ambition scenarios described in *Inputs and Assumptions for Bottom-Up and All-In Scenarios*. This ensures that the Current Measures scenario is only representative of enacted policy. These assumptions are also layered on top of broader technical/economic assumptions which may yield additional emissions reductions beyond policy alone. An example of this is our treatment of coal retirements. The Current Measures scenario assumes that additional coal plants retire beyond what utilities have announced at the time of publication, based on economic factors.

Table 2 summarizes current policies and commitments included in the analysis. The table specifically highlights actions that were modeled as being achieved by an explicit type of actor (i.e. a state, city, or business). However, we also developed assumptions for certain policy sectors that were modeled in a more top-down fashion, such as future coal plant retirements and maintenance of the U.S. land sink, that do not correspond to a specific actor. While not included in the table, assumptions for these sectors were still incorporated into the broader scenario modeling and are described in the sections that follow.

In some cases, policies at certain levels were not included due to data limitations, a lack of identifiable action at a given level (for example, no known city-level action on HFCs was identified), or a conscious decision on the part of the analytic team to exclude certain actions that lack specificity or stringency. These are marked as "not included." Actions falling in the "pledged" category (for example a city's non-binding renewable energy goal) were included in the analysis but their impacts were excluded from the Current Measures scenario itself. Finally, additional actions not shown in this table were featured in the increased ambition scenarios and are described in more detail in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section.

The Current Measures scenario includes the implementation of binding GHG caps. For the purposes of this analysis, "binding" GHG caps were limited to California's AB/SB 32 and the Regional Greenhouse Gas Initiative (RGGI) for states in the U.S. Northeast. The scenario therefore does not include a significant number of economy-wide GHG targets which have been recently adopted at the state level. These targets are included in the Bottom-up and All-in scenarios. This decision was made in order to keep modeling results conservative in the Currnet Measures scenario, and ground the scenario largely in already-enacted, sector-specific policies rather than aspirational economy-wide targets.

Table 1 | Examples of Existing vs. Pledged Policies and Actions

	EXISTING	PLEDGED
States		
Enacted state legislation	X	
Voluntary state goal		X
State mandate	X	
Executive order		X
Cities		
Enacted city ordinance	X	
City council resolution		X
Mayoral announcement		X
Climate action plan		X
Businesses		
Participation in voluntary program (e.g. EPA Gas Star)		X
Climate commitment		X

Table 2 | Summary of Actor-Specific Policies and Targets Included/Not-Included in Modeling

PRINCIPLE	POLICY/ ACTION AREA	STATE	CITY	BUSINESS
Cross-sectoral	Binding GHG Caps	Economy-wide carbon caps	Not included	Not included
	Participation in Coalition Supporting Climate Action	Not included	Not included	Not included
Decarbonizing Energy Supply	Renewable Electricity Goals	RPS/CES	Renewable (RE) targets	Utility-level commitments
	Oil & Gas System Fugitive Methane	New and existing equipment standards	Not included	Reductions reported through EPA Natural Gas STAR program
	Nuclear Fleet Retention	Zero-emissions credit / nuclear fleet maintenance	Not included	Not included
	Binding GHG Caps	Power sector specific GHG caps	Not included	Not included
Decarbonizing End Uses	Transportation	ZEV mandates, VMT targets	Municipal fleet targets, VMT targets	Not included
	HFCs	HFC SNAP/ Phasedown Regulations and Refrigerant Mgmt. Programs	Not included	Reductions reported through EPA GreenChill program
	Building & Industry energy demand	Energy Efficiency Resource Standards (EERS)	Energy efficiency targets	Not included

Accelerate Towards 100% Clean Electricity Assumptions

COAL GENERATION

The Current Measures scenario assumes that all coal units that have announced retirement will retire at their scheduled date through 2030 but also projects additional retirements. Specifically, the analysis assumes that coal plants that are uneconomic (operating consistently at a net negative margin) and fully exposed to market factors (in deregulated energy markets) will likely retire by 2025, in addition to some additional uneconomic units in regulated markets by 2030.

In the past decade, the U.S. has seen a contraction of the coal market, which is faced with an aging fleet, competition from renewables and gas, environmental controls, and local opposition. These aging units are more often than not operating at a net loss, and these economics will only continue to worsen. Many projections, such as EIA's Annual Energy Outlook, have historically failed to anticipate the decline in coal generation and project that coal will remain at 23% of generation in 2030.[4] Alternatively, other projections, including from BNEF[5] and Moody's[6] anticipate a faster contraction, falling to as little as 11% of total generation by 2030. The Institute for Energy Economics and Financial Analysis (IEEFA) notes that coal-fired capacity fell by 15.4 GW in 2018, a record, with another 12 GW of closures planned for 2019, and anticipates that this trend will continue with worsening economics.[7] Many scheduled coal plant retirements are announced only a few years in advance of their retirement, making projecting through 2030 a challenge.

In addition to coal plant closures, IEEFA notes that coal capacity factors have declined significantly, even at some of the U.S.'s largest units, and have not rebounded as coal capacity has retired. This runs counter to EIA's AEO projections that model a substantial increase in capacity factors from 54 percent today to 70 percent in 2030.

For these reasons, this report incorporates a separate economics-based projection for coal plant retirements. For 2025, the analysis assumes that units in deregulated markets that had net negative long-run margins for at least five years between 2012–2017 would close. The long-run margins were based on BNEF's analysis titled "Half of U.S. Coal Capacity on Shaky Economic Footing."[8] By 2030, we assume that more uneconomic coal units, including those in regulated markets, would be at risk. We assume that any unit in regulated markets with net negative long-run operating margins for six years from 2012–2017 would close between 2025 and 2030.

NUCLEAR GENERATION

In 2018 the U.S. had 99 GW of nuclear capacity, according the US Energy Information Administration.[9] In the Current Measures scenario, we assume 12.7 GW of at-risk capacity does not close because of existing policy actions in New York, Illinois, Connecticut, New Jersey, and Ohio. We assume that an additional 8.3 GW of other at-risk capacity does retire. The total amount of at-risk capacity was determined from information from the Union of Concerned Scientists and Beyond Nuclear accounting for every nuclear plant that has been announced as retiring before 2030. All capacity figures come from the U.S. Energy Information Administration. We also assume that the Georgia Vogtle Units currently under development come online in 2020–2021, adding 2.2 GW to the total U.S. fleet, according to the Department of Energy.[10]

POWER SECTOR BINDING GHG CAPS

For the Current Measures scenario, we assumed continued implementation of the power sector CO_2 cap-and-trade program implemented by the nine Northeastern states through the Regional Greenhouse Gas Initiative. We assume participating states achieve a projected target of a 30% reduction in power sector CO_2 emissions by 2030, relative to 2020 levels.

STATE, CITY, AND BUSINESS RENEWABLE ENERGY DEMAND

State Actions

The Current Measures scenario includes 28 currently mandated renewable portfolio standard (RPS) policies in the U.S., including the District of Columbia's target. Non-binding renewable portfolio goals (RPGs) were also included in the analysis in the pledged actions category. The renewable electricity generation driven by these policies was estimated, accounting for policy-driven demand that would be met from both hydroelectric and non-hydroelectric sources (e.g., wind, solar, and biomass). We used state-level electricity load forecasts and effective RPS demand rates (percentage of electricity load to be supplied by renewable generation) in order to produce these estimates.

We obtained baseline state-level electricity sales data from EIA for the years 1990-2017.[11] State-level electricity load projections through model year 2030 were then calculated using annual growth rates from GCAM's state electricity demand outputs.

Effective RPS rates are meant to indicate the percentage of a state's electricity load actually required to meet RPS demand in a given year, as opposed to the state's nominal RPS rates. Effective rates are often lower than nominal rates due to nuances in state RPS requirements, such as compliance multipliers for certain technologies or geographies and/or compliance exclusions for certain categories of load-serving entities (LSEs). We obtained projections of effective RPS demand rates (through model year 2030) from data and analysis provided by the Lawrence Berkeley National Laboratory (LBL).[12] We then applied these state-level effective RPS rates to the above-mentioned state load projections to generate annual renewable energy demand estimates (GWh of renewable generation required to meet the mandate). Analyses from NREL and LBL on historic renewable energy certificate (REC) procurement in the RPS market by fuel type were also used to estimate the share of RPS demand that would be met from hydroelectric vs. non-hydroelectric generation for each state.[13]

For states with non-binding RPG policies (for which LBL does not publish estimates), we produced annual RPG rate projections through model year 2030 by assuming a linear progression toward each goal starting from a 2017 baseline renewable energy mix (percentage of load generated from renewables). We derived baseline renewable energy mix from GCAM state-level electricity generation by fuel type outputs. An assumption was made that any pre-existing hydroelectric generation within the state would be used to meet these goals and would remain flat through 2030, while all future renewable energy demand driven by the goals would be met with non-hydroelectric sources.

City Actions

For city commitments, we estimated the impact of 144 current renewable electricity targets (e.g., a city goal of supplying 100% of its electricity from renewables). Impact was quantified in terms of renewable energy demand (in GWh), derived from city-level electricity load forecasts and city renewable energy target data (percentage of electricity load required to meet goals). These targets were categorized as "pledged actions" and therefore included only in the higher ambition scenarios described in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section.

We obtained city-level electricity load estimates from the National Renewable Energy Laboratory's State and Local

Energy Data (SLED) tool, which contains city-level activity data estimates for over 23,000 incorporated towns and cities in the U.S.[14] SLED electricity consumption estimates by city (in MWh) for the year 2013 were projected forward through 2017 using state-level electricity consumption growth rates derived from EIA.[15] The city-level consumption estimates were then projected forward through model year 2030 using growth rates from GCAM's state electricity demand outputs.

We collected data describing city-level renewable energy targets from multiple sources, including: city commitment information from the Sierra Club's *Ready for 100* campaign; city commitment data published by CDP; DSIRE; and individual city Climate Action Plans, press releases, and city council resolutions.[16 17 18] We checked for any inconsistency in a city's target and base year or duplication of city entries across the data sources we pulled information from.

A city's baseline renewable energy mix (percentage of electricity load met by renewable sources) was calculated using GCAM state-level electricity generation by fuel type outputs, with the assumptions that a) a city electricity load's mix of renewables matches that of its state and b) for the purposes of city-level renewable energy targets, only non-hydroelectric renewable sources would count toward the target's baseline mix. To calculate annual renewable energy demand through 2030, we further assumed that a city's policy-driven renewable energy demand (percentage of renewable energy required to meet its goal) increases linearly in even annual increments until 100% of the goal is reached in the target year. We then applied the annual target rates to the projected city-level electricity load data through model year 2030 to generate annual renewable energy demand estimates (gigawatt hours or GWh of renewable energy required to meet the target).

Utility Actions

Commitments to decarbonize electricity supply and increase the share of renewable generation on the part of 31 utilities in the United States were also assessed. These targets were categorized as "pledged actions" and therefore included only in the higher ambition scenarios described in the the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section.

Data on utility-level commitments were compiled by WRI and also sourced from a tracker developed by Smart Electric Power Alliance (SEPA).[19] Data across multiple lists were cross-checked to avoid inclusion of duplicate actions. We quantified the impact of these commitments by estimating baseline renewable generation levels for each utility's total present-day fleet of power generating facilities and then assuming that goals will be met through directly increasing the level of renewable energy generation relative to fossil sources (e.g. coal and gas).

We calculated baseline utility generation mix (i.e. the relative share of generation by fuel type within a utility's portfolio) using data on plant-level assets curated by Bloomberg New Energy Finance (BNEF).[20] Historic generation across all plants in a company's portfolio was summed by fuel type (e.g. wind, solar, gas), and the relative share of each fuel was calculated as a percentage of the total. For companies that have assets in multiple grid regions, we calculated generation mix on a region-by-region basis. For example, a single company may have assets in several regions of the United States. However, the majority of its most carbon-intensive generation sources may be concentrated in one or two specific power regions. Calculating generation mix on a regional basis thus allows for a more accurate representation of where fleet turnover would likely need to take place in order to achieve significant, additional decarbonization.

To translate targets into assumed increases in future renewable generation, commitments were broken out into three basic types: carbon neutral or clean energy goals, renewable energy goals, and emissions reduction goals. We defined carbon neutral / clean energy goals and renewable energy goals as those stating the objective of achieving a certain percentage of generation from clean or renewable sources by a set year. To calculate these goals, we assumed that a company's renewable or clean energy generation mix (calculated as described above) will increase linearly until the goal is achieved in the target year. We also assumed that any nuclear generation in the company's regional portfolio would contribute to a company's clean energy mix while only wind, solar, and geothermal would contribute to a company's renewable energy mix.

In contrast to renewable and clean energy goals, we defined emissions reduction goals as those stating the goal of reducing emissions by a specific percentage from a base year. To convert these goals into metrics that could be used in our analysis, a simplifying assumption was made that the reduction in emissions would be achieved through an increase in generation from renewable sources relative to fossil-fuel based sources. The exact percentage of increased renewable generation and decreased fossil-based generation is calculated as the total reduction goal (e.g. 50%) minus current progress made toward the goal to-date since the target base year, multiplied by the company's current fossil-fuel generation mix. It is then assumed that the company's renewable generation mix will increase linearly until the goal is achieved in the target year. For example, if a company has a 50% reduction target (T) by 2030 from a 2005 base year, has an already achieved emissions reduction level (A) of 15% relative to the target base year, currently has a renewable generation mix (G_r) of 10 percent, and a fossil generation mix (G_f) of 50 percent, the company's projected future renewable generation mix for target year 2030 is calculated as:

Projected RE generation mix in 2030 =

$$\frac{G_r + (T - A) * G_f}{100} = 27.5\%$$

As in step one of this methodology, for companies with power-generating facilities in multiple grid regions, these calculations are done on a region-by-region basis. An implication of this assumption is that a company's generation mix would shift significantly in regions where its share of renewable generation is currently low and fossil-based generation is high, whereas little impact would be seen where the opposite is true.

As a final step, we calculated the assumed renewable generation (in GWh) required to meet each utility commitment by multiplying the projected renewable generation mix for each company (calculated as described above) by the company's total generation within in each grid region for each model year. We produced projections of total electricity generation for each utility at the grid region level through model year 2030 by taking the baseline generation for each utility from BNEF data at the company and grid region level and applying regional-level electricity generation growth rates from GCAM outputs.

State-Level Aggregation

We aggregated assumed renewable energy generation resulting from state, city, and utility actions described above at the state level, accounting for overlap across the three different levels of action. As a first step, generation from city and utility commitments, derived from the above-described methods, is summed at the state level to produce first order estimates of renewable generation resulting from these actions without accounting for overlap. For the city level summation, generation is summed for the state in which each city is located. For the utility level summation, we allocated each utility's projected renewable generation to states by calculating state allocation shares representing the percentage of each grid region's generation that serves a particular state. This process involved mapping total grid region generation to states using EPA's eGRID database.

We then accounted for overlap as follows:

- To account for overlap between city-level targets and state RPS policies, we used a net percentage approach. Under this approach, only additional GWh demand from city goals in a given model year is counted and added on to state RPS GWh demand to produce an aggregate total. For example, a city with a 50% goal for the year 2025 in a state with a 40% RPS rate in the same year would have a net 10% that could be applied to the city's electricity load and added on as additional renewable energy demand at the state level. Alternatively, if the city's projected renewable target were less than or equal to the state's 40% target, no additional renewable demand would be included for the city in this model year.
- To account for overlap between utility commitments and state RPS policies, we similarly relied on a net percentage approach. For example, if a utility commitment as calculated using the above approach would result in renewable penetration of 50% within a utility's portfolio of assets in a given model year, and the utility serves a state that has a 40% RPS rate in the same year, only 10% of the utility's generation serving the state would be assumed to be additional to the state target. Again, no additional demand would be added to the state RPS total if the target were less ambitious.

Key simplifying assumptions associated with this approach are as follows:

1. The city and state overlap approach assumes that electricity providers across each state are in uniformly in compliance with RPS requirements. More specifically, we assume the share of renewables on the grid for each city matches the states RPS target in each model year. City renewable demand that exceeds the ambition of state goals is then assumed to be additional rather than being dampened by potential non-compliant jurisdictions. We based this assumption in part on historic RPS achievement on the part of load-serving entities as well as consultations with experts at both NREL and LBNL, with the important caveat that it is intended only for the sake of estimating impact in aggregate and does not reflect the full complexity of local electricity markets.
2. The approach further assumes that city-wide targets and utility commitments are met with a combination of a) baseline, pre-existing renewable energy generation (e.g., generation capacity already established to meet RPS compliance or simply due to favorable economics) and b) additional procurement and build-out of renewable generation facilities. In other words, the renewable energy generation driven by city targets and utility commitments is not entirely additional to state RPS demand or purely economic generation capacity already on the grid.
3. No assumption is made in regards to the specific mechanism by which cities procure additional renewable energy (e.g., local photovoltaic (PV) installations, REC purchasing, green tariff utility products) except that the RECs associated with the additional procurement are retired at the city-level and not re-sold (after factoring for overlap with RPS-driven or pre-existing

economic renewable generation). We based this assumption in part on consultations with experts, with the understanding that it is inherently simplistic, may not reflect the on-the-ground reality for a specific city's context, and is intended only for the purposes of estimating impact in aggregate.

4. The utility approach assumes that the share of a utility's total generation at the grid region level can be allocated to states based on a mapping of grid region-to-state generation data using EPA's eGRID database,[21] which provides annual electricity generation totals for 2016 by state, grid region, and balancing authority. This implies that a) state load shares for each region have remained relatively constant over time and b) state load shares calculated using this approach are a viable proxy for the generation delivered to each state's power market by a given utility.

We heard from and consulted with a variety of experts on these assumptions. Some expressed concern that they could lead to overly conservative estimates. For example, they pointed out that in order for cities to claim full compliance with their renewable targets, they would have to retire the appropriate quantity of RECs and would be unlikely to rely on RPS compliance to achieve part of the goal. Others were skeptical that city goals would be met with 100% unique RECs, with some stating that any increase in renewable generation should be attributed to states and regulated entities overachieving on their goals and taking advantage of changing economics, irrespective of city goals. It is our view that the above assumptions represent a "middle of the road" approach that attributes some additional generation to city-level and utility-level targets while at the same time assuming considerable overlap with RPS compliance and otherwise economic generation.

OIL AND GAS SYSTEMS METHANE

In April 2012, the EPA issued federal New Source Performance Standards (NSPS) (for subpart OOOO) regulating volatile organic compound (VOC) emissions from new, modified, and reconstructed sources. This regulation also indirectly regulated methane emissions as an incidental co-benefit.[22] In 2016, EPA released an amended standard (for subpart OOOOa) to directly regulate methane emissions. The 2016 regulation was rolled back in August 2019 and has an uncertain future legal status.[23] Similarly, the Bureau of Land Management's (BLM) *Waste Prevention, Production Subject to Royalties, and Resource Conservation* rule[24] is also under legal review at the time of the release of this analysis.[25] Given that both the BLM and NSPS regulations face potential rollbacks or legal uncertainty, we did not assume that regulated emissions sources are 100% compliant in the Current Measures scenario and instead assume that 75% of sources would be covered. This assumption was used simply as a means of representing uncertainty and should not be interpreted in any way as an assessment on the part of the analytic team of the likelihood of future compliance with the regulations in question.

To estimate the impact of these regulations, we obtained data on state level emissions and projected reductions from independent modeling and analysis conducted by the Environmental Defense Fund (EDF). State-level modeling outputs provided by EDF included methane emissions reductions under multiple policy scenarios, including a no-policy reference case scenario, a fully implemented federal NSPS scenario (OOOO and OOOOa), a federal BLM rule scenario, and individual state policy scenarios. The modeling outputs accounted for potential overlap across the various state and federal regulatory regimes within each scenario. We quantified impacts of the above-mentioned federal regulations as the percentage below reference case emissions within each state under the fully implemented NSPS and BLM scenarios. These figures varied from state to state, as the emissions impacted by federal rules depends on the extent of oil and gas production, processing, and transmission activities within each state boundary. Per our above assumption regarding compliance uncertainty, we assumed that only 75% of emissions sources would be covered by the federal regulations, however it is important to note that this assumption did not have a material impact on results for states with policies already in place that match or exceed the emissions reduction potential of the federal rules.

State Actions

At the state level, the analytic team modeled the impact of current state-level policies that reduce oil and gas methane emissions either explicitly or as an incidental co-benefit of policies aimed at VOC emissions reductions. These included current regulations in the states of California, Colorado, Pennsylvania, Utah, Ohio, and Wyoming.

To estimate the impact of these state policies, the above-mentioned EDF modeling output data were relied upon. Reductions were quantified in terms of percentage below reference case emissions in the state-level policy scenarios. Any overlap between federal and state policy impacts was also accounted for, as EDF's analysis allowed for the assessment of state policies on their own as well as the combined impact of state and federal policies. In contrast to our federal policy assumptions, we assumed that state level policies would be achieved in full through 2030.

Corporate Actions

In addition to state and federal regulations, we also estimated the impact of voluntary commitments on the part of gas companies to reduce methane emissions through EPA's Natural Gas STAR program. These commitments were categorized as "pledged actions" and therefore included only in the higher ambition scenarios described in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section.

EPA's Natural Gas Star program currently comprises over 100 corporate partners with commitments across the gas supply chain. These include efforts to replace pneumatic devices and compressors at gathering sites with more efficient low- or zero-bleed equipment and adopt more ambitious replacement rates of aging cast-iron distribution infrastructure. Estimates of the annual reductions in emissions resulting from these commitments are included in the annex tables to the EPA's Greenhouse Gas Inventory.[26] These annual reductions are broken out by the gas system segment in which they occur (e.g., production, transmission and storage, distribution) but are provided only at the aggregate national level (rather than at a source-specific or company-specific level of granularity). The most recent year for which Natural Gas STAR reductions are reported by the EPA is 2017. To estimate continued reductions for the years modeled, we assumed that reductions would increase proportionally with projected increases in oil and gas production activity, derived from EIA's AEO projections. Since the Natural Gas STAR reductions are not reported at the state level, we used emissions data from EPA's Facility Level Information on Greenhouse gases Tool (FLIGHT) to disaggregate the reported reductions. To do this, we calculated total methane emissions by segment (e.g., production, distribution) and facility location within the FLIGHT database and then allocated the reductions proportionally based on each state's share of the emissions totals by segment.

State Level Aggregation

Annual reductions in methane emissions resulting from the Natural Gas STAR program as reported by the EPA already account for overlap with federal regulations.[27] Thus, for states without current standards that build upon federal NSPS and BLM rules, the disaggregated state-level reductions were counted as additional to the impact of federal policies. However, in states with existing standards, a simplifying assumption was made that voluntary corporate actions would contribute to the achievement of these regulations but would not result in any incremental reductions.

Decarbonize End-Uses Assumptions

ENERGY EFFICIENCY

State Level Actions

In the Current Measures scenario, we included the impact of 20 binding state-level energy efficiency resource standards (EERS) currently in place. These policies establish energy savings targets for electricity and/or gas demand that regulated entities within the state, such as utilities, are required to achieve. We also included seven non-binding state EERS policies in the pledged category of actions that are limited by a cost-cap or allow certain groups of customers to opt-out of the program; these are included in the higher ambition scenarios described in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section.

We obtained historic state-level commercial, residential, and industrial electricity and gas demand data (i.e. total amounts delivered to customers) from the EIA for the years 1990-2017.[28] [29] We then estimated annual demand projections through model year 2030 using growth rates from GCAM's state electricity and gas demand outputs. To quantify the projected impact of current EERS policies, we applied state-level average annual incremental electricity and/or gas savings targets as estimated by ACEEE's 2018 State Energy Efficiency Scorecard[30] to the state's projected demand. Because standards do not always apply to all energy sales within a state, we adjusted energy savings by the percentage of electricity or gas sales covered by the target. For state energy efficiency targets with specified end dates, we assumed that incremental energy savings would still be realized through the average measure lifetime as reported to EIA by utilities located in the state.[31]

City Level Actions

We assessed the impacts of a total of 40 city-level energy efficiency targets to reduce electricity and/or gas consumption in residential, commercial, and industrial buildings. These targets were categorized as "pledged actions" and therefore included only in the higher ambition scenarios described in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section.

Data describing these targets were sourced from ACEEE and individual city government websites and climate actions plans.[32] To estimate the 40 cities' baseline energy use, city-level commercial, residential, and industrial electricity and gas demand data was obtained from the NREL's SLED tool.[33] For internal consistency, SLED data is used for all cities in our aggregation analysis, except Washington, DC (which is available in EIA's state databases). The SLED tool contains city-level activity data estimates for over 23,000 incorporated towns and cities in the U.S. SLED electricity and gas consumption estimates by city for the residential, commercial, and industrial sectors for the year 2013 were projected forward through 2017 using state-level demand growth rates derived from EIA. The city-level consumption estimates were then projected forward through model year 2030 using growth rates from GCAM's state demand outputs.

For each city, electricity and gas savings were estimated based on the sector-specific reduction goals within the data describing the targets. For cities that have targets which apply only to certain sectors, the target was applied to the proportion of energy demand for that sector only. Several cities had targets that required additional assumptions to be made. Examples of these additional assumptions are described in Table 3.

Table 3 | Modeling assumptions made for nuanced city energy savings targets

CITY	TARGET	ASSUMPTION
Denver, CO	Reduce energy consumption of commercial and multi-family buildings 10% by 2020 and 20% in the decade following.	Assumed that the Denver metro area proportion of single family housing & multi-family housing is similar to the U.S. Census estimates for the Denver metro area.
Los Angeles, CA	By 2035, reduce energy use per square foot – for all building types – by 30%.	Applied Los Angeles's 15% EE target due to data limitations for floor area projections. Assume 15% reduction in electricity demand compared to reference case scenario projections from 2020 onward.
Louisville, KY	Decrease community-wide per capita energy use 25% below 2012 levels by 2025.	Assumed Louisville's population (2013) grows consistently with Kentucky's projected population growth rate; applied target to residential, commercial, and industrial sectors only.
New York, NY	Reduce GHG emissions from all private buildings by 30% from a 2005 baseline by 2025.	Assumed 30% GHG reduction target resulted in 30% electricity and gas savings.
San Antonio, TX	Reduce energy use for all buildings within the city from 116 kBTU per square foot in 2014 to 90 kBTU per square foot in 2040.	Did not include target in this analysis due to projected square footage data unavailability.
San Diego, CA	Reduce energy use by 15% per housing unit in 20% of residential housing units by 2020 and 50% of units by 2035.	Assumed each residential unit consumes the same amount of electricity.
Seattle, WA	Reduce GHG emissions by 82% from buildings by 2050 (relative to a 2008 baseline). These reductions should come from a 45% reduction in commercial energy use and a 63% reduction in residential energy use over that same time.	Assumed that electricity consumption is reduced in line with the city's GHG reduction target; modeled commercial and residential savings through 2050 and added in industrial proportion of reference case electricity demand through 2030.

State Level Aggregation

Energy savings resulting from city energy efficiency targets were summed up to the state level (e.g., the energy savings from Cleveland's and Columbus' targets were summed up to an Ohio-level estimate of city-level targets). These state totals of city-based action were then compared to the state totals resulting from state-level action. This analysis assumes that 100% of the savings from a city target is additional if the city is served by a municipal utility that is exempted from the state's EERS, but that only 25% of the savings associated with a city target is additional if the city is served by an investor-owned utility that must comply with the state EERS. For this latter case, there is little to no literature available that examines what portion of a city's energy savings can be attributed to utility-sponsored vs. city-sponsored programs. However, at least some city-sponsored actions can be counted as additional (e.g., building codes, energy performance service contracting, benchmarking and transparency regulations, etc.), so experts believe that it can be assumed that 25% of a city's target is achieved through actions outside of utility-sponsored programs.[34] Note, this assumption could vary drastically across cities. The result is an estimate of total electricity (TWh) or gas (MMcf) savings from state and city energy efficiency targets, taking into account potential double counting. No additional efficiency gains were assumed beyond those embedded in the baseline for other fuels besides electricity and gas.

VEHICLES MILES TRAVELED (VMT) REDUCTIONS

State Level Actions

In the Current Measures scenario, we included the estimated impact of three state vehicle miles traveled (VMT) reduction targets – California, Vermont, and Washington. Information on these targets was initially obtained from the ACEEE state policy database.[35] Historical state-level VMT was obtained from the DOT's FHWA Highway Statistics Publications (1990-2017)[36]. GCAM's VMT growth rates were used to estimate each state's baseline VMT projections through model year 2030. While GCAM's VMT projections do not take into account subnational policies, the model does incorporate projected changes in adoption of vehicle technologies for each vehicle category as a result of federal CAFE standards for light-, medium-, and heavy-duty vehicles. To accommodate any state-based targets that only cover certain vehicle categories, the vehicle class fleet percentage (e.g., the % of light-duty vehicles out of all vehicle classes) were estimated based on GCAM outputs. To calculate per capita-based VMT targets for states, we used state-level historical population data and growth projections from GCAM.

For each target, the projected reduction in VMT was estimated by first considering its specifications – whether the is target based on a reference case VMT scenario, whether it is adjusted for population, and whether it only applies to certain vehicle categories. For this latter target type, we apply the target to the applicable vehicle category (e.g., light-duty) only and assume VMT for other on-road modes (e.g., medium- and heavy-duty) continues to grow using GCAM's baseline growth rates.

City Level Actions

We assessed the impact of 15 city-level VMT reduction goals. These targets were categorized as "pledged actions" and therefore included only in the higher ambition scenarios described in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section.

Data describing these goals were sourced from ACEEE's city policy database and individual city government websites and published climate action plans.[37] City-level VMT baseline data were obtained from the NREL SLED tool. The SLED tool includes estimates of city-level VMT based on scaling factors derived from city, state, regional, and national data from DOT and the U.S. Census.[38] The SLED tool only provides city-level estimates for the year 2013. To estimate historical VMT (prior to 2013) and to project VMT estimates from 2013 to 2017, we assumed that a given city's VMT rate of change matched that of its state in the GCAM state-level outputs. We then projected city VMT through model year 2030 using GCAM's state-level growth rates. To assess per capita VMT targets, we used U.S. Census data at the city level estimated for 2010 to 2017. For years prior to 2010 and beyond 2017, we used state-level growth rates from the GCAM population baseline to project the city population back from 2010 and forward from 2017.

State Level Aggregation

Our analysis conservatively assumes that a city-level VMT target would only be additional to the impact of a target within the state if the estimated decrease in VMT actual exceeds the state level goal in a given model year. In most instances, the expected city VMT reductions were not larger than the state's VMT reduction target. For city-level VMT targets occurring in states without targets, 100% of the impact was included in the analysis.

VEHICLE STANDARDS AND ZERO EMISSIONS VEHICLE REGULATION AND PROCUREMENT

State Level Actions

The Current Measures scenario assumes that existing vehicle standards (for light-, medium-, and heavy-duty vehicles) and zero emission vehicle (ZEV) programs remain operative, despite uncertainty created by the current administration's actions. The Current Measures scenario assumes that all states and automakers align with the California compromise on vehicle greenhouse gas standards – achieving 3.7% improvements annually, beginning in the 2022 model year (MY) and extending through the 2026 MY.[39]

Current Measures also includes the impact of California's Zero Emissions Vehicle program and the 10 states in addition to California that had signed on to the regulation at the time of this analysis. California's ZEV program requires manufacturers to produce an increasing number of ZEVs, with the current regulation covering model years 2018-2025 for light-duty vehicles.[40] While manufacturers can fulfill standards by manufacturing a minimum amount of pure battery electric vehicles (BEVs), they are also able to use credits earned by manufacturing "transitional ZEVs" such as plug-in hybrid electric vehicles (PHEVs) and also by manufacturing fuel cell electric vehicles (FCEVs). Therefore, manufacturers may be able to meet their targets with a mix of these different types of vehicles. This analysis assumes that the state ZEV targets are fully met with BEVs or PHEVs. While FCEVs are also a compliance option for manufacturers, we made a simplifying assumption that over the next decade fuel cell technology will not materially contribute to the achievement of the states' ZEV goals.

Baseline PHEV and ZEV sales at the state level are calculated by taking EIA's AEO historic and projected vehicle sales data at the census region level through model year 2030 and disaggregating to individual states using vehicle registration totals published by FHWA.[41] [42] Disaggregation factors are calculated as the share of total vehicle registrations within each census region represented by a given state. A further simplifying assumption is made that these state-level shares will remain constant through 2030.

Estimates of the annual number of BEV and PHEV sales resulting from state ZEV mandates that would be additional to baseline sales through 2025 were derived from analysis conducted by EIA.[43] For years beyond 2025, it was assumed that BEV and PHEV sales percentages in ZEV mandate states would continue to increase in-line with annual growth rates derived from AEO. California's commitment to further increase ZEV sales to approximately 40% of total sales by 2030 was also assessed and included in the pledged category of actions in this analysis.

City Level Actions

We assessed the impact of eight quantifiable city electric vehicle procurement goals for the light-duty vehicle sector. These targets were categorized as "pledged actions" and therefore included only in the higher ambition scenarios described in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section.

Data describing the city-level fleet procurement goals were sourced from ACEEE and individual city government websites and published climate action plans.[44] To quantify the goals, we assumed a linear trend in cumulative procurement from the year enacted, or the year the city reported when they procured their first zero emission vehicles, to the target year. Once the target year is reached, we assume that the cumulative total number of EVs will be maintained by the city through 2030.

State Level Aggregation

Our analysis conservatively assumes that city-level procurement targets occurring within ZEV mandate states would contribute to the state-level targets and result in no additional EVs on the road beyond the state goals. City level targets occurring in states without ZEV targets would be additional to the EV sales baseline. City fleet procurement goals are all modeled as additional to state fleet procurement goals since those two types of fleets do not overlap.

After accounting for overlap across city and state level actions, total electric vehicle miles traveled (EVMT) is calculated at the state level by multiplying annual sales and procurement estimates from the above-described methodology by average annual travel outputs from GCAM. The result is an estimate of additional annual EVMT resulting from BEV and PHEV sales for each model year at the state level.

HYDROFLUOROCARBONS (HFCS)

HFCs are a small, but rapidly growing source of GHG emissions that are used as refrigerants, foams, aerosols, and in other applications and are as much as 12,000 times more potent than CO_2. In 2015, the EPA issued rules through its Significant New Alternatives Policy (SNAP) program that classified certain uses of HFCs as unacceptable (Rule 20) and approved other alternatives that can be used in their place (Rule 21). However, Rule 20 was vacated by the DC Court of Appeals in August 2017.[45] The EPA also issued a rule in 2016 updating the refrigerant management requirements under the Clean Air Act. The rule expands refrigerant management practices under Section 608 to cover HFCs, and would reduce GHG emissions by 7.3 million Mt CO_2e annually starting in 2019.[46] In October 2016, the parties to the Montreal Protocol agreed to the Kigali Amendment, which calls for a global phasedown of HFCs starting in 2019, with most countries capping production and consumption by 2024.

State Level Actions

In January 2011, California began addressing refrigerant leaks through its Refrigerant Management Program (RMP). The RMP requires HFC leak inspections, registration, and reporting to the state Air Resources Board, and is expected to reduce GHG emissions by 4.5 Mt CO_2e each year.[47]

Because GCAM's baseline projections do not include any existing federal or state measures, we first adjusted GCAM's baseline to account for the EPA's Section 608 leakage repair requirement. To do this, we allocated the annual savings estimated by the EPA (7.3 Mt CO_2e) to each state based on state population. We then assumed California achieved greater emissions reductions as a result of its stronger state standards.

Given the uncertainty about the future of the EPA's SNAP program, California adopted a regulation in March 2018 that would preserve and continue some of the vacated SNAP prohibitions within the state as a backstop against federal inaction or abdication. To quantify the impact of this measure, we utilized California's estimates of the maximum impact of this regulation for years 2018 through 2030 as depicted in Table 4.[48]

Table 4 **Reductions (metric tons of CO_2e) each calendar year, shown by equipment production year for all emissions sectors covered by California's SNAP regulation**

PRODUCTION YEAR BELOW	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
2018	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
2019		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
2020			0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
2021				0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
2022					0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
2023						0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
2024							0.35	0.35	0.35	0.35	0.35	0.35	0.35
2025								0.36	0.36	0.36	0.36	0.36	0.36
2026									0.36	0.36	0.36	0.36	0.36
2027										0.36	0.36	0.36	0.36
2028											0.37	0.37	0.37
2029												0.37	0.37
2030													0.37
MAXIMUM ANNUAL REDUCTIONS	0.3	0.6	0.9	1.3	1.6	2.0	2.3	2.7	3.0	3.4	3.8	4.1	4.5

▲ Source: California Air Resources Board, Table B2.

In 2019, the states of Washington and Vermont adopted similar policies to preserve federally vacated SNAP rules within their jurisdictions. To estimate the impact of these actions, we converted the assumed abatement in HFC emissions for California (in metric tons CO_2e) to a percentage below baseline state level HFC emissions. We then assumed Washington and Vermont reduce their state level HFC emissions by the same percentage for years 2020-2030.

Business Level Actions

We also assessed the impact of business-level actions to reduce HFC emissions through EPA's GreenChill program. These targets were categorized as "pledged actions" and therefore included only in the higher ambition scenarios described in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section.

According to the EPA, the average U.S. supermarket emits approximately 1,500 metric tons of CO_2e annually as a result of refrigerant leakage, equating to a leakage rate of about 25%. Through EPA's GreenChill program, 43 supermarket chains have committed to reducing their HFC emissions, representing over 10,000 individual stores (28% of all stores in the U.S.).[49] GreenChill partners have, on average, reduced their leakage rate by about 44% compared to the average supermarket.[50] As of 2018, 215 stores were certified as having achieved even greater emission reductions (Table 5). These stores have taken a wide range of actions to reduce their emissions – including addressing leaks, upgrading equipment, and switching to refrigerants with lower GWPs.

Table 5 | **Number of GreenChill Certified Stores**

CERTIFICATION LEVELS	EMISSIONS REDUCTION RELATIVE TO AN AVERAGE STORE			NUMBER OF STORES
	MIN	MAX	AVERAGE	
Platinum	95%	98%	97%	67
Gold	64%	84%	74%	31
Silver	50%	78%	64%	117

▲ Source: EPA GreenChill

To estimate the GHG impact of these voluntary corporate actions to reduce HFC emissions, we first obtained the number of partner and certified stores by state. To develop the baseline, we assumed each store produced the national average level of HFC emissions for the supermarket sector (1,556 metric tons of CO_2e per year) from 2017 to 2030.[51] We then assumed partner stores reduced their emissions by the average partner rate (44%) while GreenChill-certified stores reduced their emissions by the average reduction reported to be achieved by their certification level.

State Level Aggregation

Our analysis conservatively assumes that emissions reductions achieved by voluntary corporate actions through the GreenChill partner and certified stores are likely to help achieve state level HFC regulations to phase down HFCs emissions such as those adopted in California, Washington, and Vermont. GreenChill savings are also assumed to overlap with existing refrigerant management regulations, such as the EPA's Section 608 standards and California's more ambitious state-level standards.

Enhance Ecosystems Assumptions

LAND USE

According to the EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017*,[52] the land sink was -714 metric tons of CO_2e in 2017. Since it began its reporting, the EPA's estimate of carbon dioxide removals via the land sink has varied significantly, reflective of high uncertainty in land sector estimates as well as continued methodological improvements. Projections are even more uncertain with EPA[53] and USDA models showing divergent land sector estimates. This uncertainty is illustrated in the 2016 Biennial Report which showed land sector emissions growing by as much as 200 million metric tons by 2030 or declining by 200 million metric tons.[54] Efforts are underway to improve the uncertainty associated with current and projected land sector estimates,[55] yet developing new projections for land sector is out of the scope of the expertise of the team working on this report. Therefore, our Current Measures scenario assumes a constant sink through 2030 and estimates uncertainty about this sink using an adjusted range of high and low projections from the Biennial Report.

Cross-Cutting Assumptions

CARBON PRICING AND GHG TARGETS

California's economy-wide AB32 and SB32 GHG emission reduction target is incorporated in the Current Measures scenario. We assumed California's 2030 target of a 40 percent economy-wide reduction in emissions from 1990 levels is fully achieved.

OTHER METHANE AND NITROUS OXIDE

Methane (CH_4) from livestock, landfills, coal mining, and crops, and nitrous oxide (N_2O) from crops and nitric and adipic acid production also contribute to climate change. A small amount can make a big difference because methane has a global warming potential of 25 times that of CO_2 over a 100-year time horizon (and 86 times that of CO_2 over a 20-year time horizon) and nitrous oxide 298 times that of CO_2. In the Current Measures scenario, we used projected emissions for these gases from EPA.[56] Through 2030, EPA projects that emissions in all these sectors grow slightly, except coal mining methane, which declines.

While the same modeling approach was taken for all of these non-CO_2 sectors, the measures that will be taken to address them vary. In the report, we categorize non-CO_2 emissions from coal mining into Principle 1 (Accelerate Clean Electricity and Energy Supply), nitric and adipic acid into Principle 2 (Decarbonize End Uses), and livestock, landfill, and croplands into Principle 3 (Enhance Ecosystems).

Summary of Key Uncertainties & Limitations

While we have endeavored to capture as much activity by states, cities, and businesses as possible and make reasonable assumptions in our aggregation methodology, our approach is subject to some uncertainties and limitations:

- Because actions in one sector (e.g., building energy efficiency or electrification of transportation) affect other sectors (e.g., demand for electricity), it is important to assess the impact of these same actions in an integrated fashion. The sector-specific results from the phase of the analysis described in this section do not take these cross-sector interactions into account, though these interactions are addressed in GCAM in the phase of the analysis described in the *Socio-Economic Analysis Methodology* section.

- While we made efforts to account for impacts that are already embedded in the GCAM baseline that would naturally overlap with the policies and targets being quantified (for example, the amount of policy-driven energy efficiency gains already included in GCAM state-level data), there remains some uncertainty around the potential for our estimates to be over- or under-estimating impact.
- Additional uncertainty arises from explicitly disregarding Level 2 "contributing" policies that are complementary to the Level 1 policies we quantified or are at times enacted even in the absence of a top-down Level 1 goal (for example, a city without a renewable energy target may still promote new wind and solar generation through PPAs, siting and/or permitting reforms, or other mechanisms not modeled in this analysis). The result is that we may in some cases be underestimating the full impact of subnational climate-friendly actions in the U.S.
- Due to time and data limitations, we were largely limited to including only those actors that report the policies and actions they are taking publicly or to a third-party organization or coalition.

INPUTS AND ASSUMPTIONS FOR BOTTOM-UP AND ALL-IN SCENARIOS

Overview of the Scenarios

While the Current Measures scenario was focused on existing policies, the Bottom-Up and All-In scenarios were modeled based on analysis and assumptions by the study team about what policies or actions might be put into place and the best available data for what impact those actions might have. Context on how and why the study team selected certain actions and how they chose to model them is included in the scenario descriptions below.

The Bottom-Up scenario projects how much a significant expansion of state, city, and business climate action could reduce greenhouse gas emissions, even without the help of the federal government. In this scenario, we assume that as communities reap the emissions, economic, and public health benefits of their existing climate-friendly policies, such as those modeled in Current Measures, additional states, cities, and businesses are encouraged to follow suit and enact similarly ambitious policies, scaling the most impactful of the now tried-and-true actions. This momentum is further accelerated due to improving economics of clean technologies and growing citizen action. Though, as has been the case historically, not all states will act equally. Therefore, to facilitate our scenario analysis, we grouped states into three different tiers depending on their current policies and historical willingness to lead on climate.

For the Bottom-Up scenario, we anticipate that Tier 1 states that have been the "first-movers" will continue to lead the way on ambitious climate action, adopting the most numerous and most ambitious climate targets and policies. We identified these states by attributes such as membership in leadership organizations (e.g. U.S. Climate Alliance); vocal leadership in support of climate action; ambitious and mandatory emissions reduction targets or standards; and on-the-books climate policies. We modeled 20 Tier 1 states and districts, typically including 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.

States that are currently taking some measures to reduce emissions but not as quickly are categorized as Tier 2. Our Bottom-Up scenario assumes that these "fast-follower" states will implement some of the policies developed by the Tier 1 leader states but to a lesser extent. We modeled nine Tier 2 states, typically including Arizona, Iowa, Michigan, Missouri, Nevada, North Carolina, Ohio, Virginia, and Wisconsin.

Finally, we anticipate that Tier 3 states that have done little with respect to passing climate policies will, for the most part, continue the status quo, even if those new policies would be cost effective. We modeled 22 Tier 3 states, typically including 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. While each of these states do have some clean energy and lands efforts underway, for the purposes of this analysis, we assume they will continue at a slow pace.

These tiers are used for modeling purposes and intended to be illustrative, as in reality, there is no bright line between states. Some states defined as Tier 2 or Tier 3 may take leadership-level actions in some sectors, and not all Tier 1 states will take the most ambitious actions across all sectors of the economy. Our tiered approach is intended to approximate the scale of action across all 50 states. The policies that were modeled for each tier of states depends on the sector and are explained below in more detail. We did not use the tiered approach for all policies and sectors. Specifically, for coal retirements and gas methane standards, we used other metrics to model state and city actions.

City and business activities are also included in the Bottom-Up scenario modeling. In order to avoid double-counting in areas where state, city, and business-level policies target the same emissions sectors or policy areas, the modeling factors out overlapping ambition, particularly where cities and businesses taking action are located inside a Tier 1 state. The Bottom-Up scenario assumes that federal policy remains frozen through 2030.

The All-In scenario projects how much greenhouse gas emissions could be reduced with renewed and comprehensive engagement from the federal government, including new legislation that builds on the policies of the most ambitious states in the Bottom-Up scenario. In this scenario, after 2020 the Executive Branch and Congress implement a suite of new measures to decarbonize the economy. These new policies complement the efforts of states, cities, and businesses and fill in the gaps where federal policy is better suited. Our comprehensive All-In scenario requires expansive new policies and a massive buildout of new technology and infrastructure.

Accelerate Toward 100% Clean Electricity Assumptions

RENEWABLES DEPLOYMENT

For the Bottom-Up scenario, we assumed that Tier 1 states achieve at least a 60 percent renewable portfolio standard by 2030, consistent with the most ambitious state policies currently in place. Tier 2 states enhance their ambition, achieving at least a 40 percent renewable portfolio standard by 2030. Finally, Tier 3 states achieve a 20 percent renewable portfolio standard by 2030.

The All-In scenario assumes all states, particularly in the Tier 3 category, further increase renewable penetration rates to at least 35%. Combined with assumptions regarding coal retirements, gas generation, nuclear, and carbon capture, utilization, and storage (CCUS) described below, clean energy generation in the United States reaches 75 percent by 2030.

The Bottom-Up and All-In scenarios also assume that all existing and pledged actions described in the *Overview of GCAM-USA* section are fully achieved. Any overlap between the heightened renewable portfolio standards described in these scenarios and current policies and commitments from state, city, and business actors are also accounted for using the methodology described previously.

COAL GENERATION

Both scenarios model what is possible with greater local and state-led actions targeting utilities, plant operators, and public utility commissions (PUCs) as well as strong policy interventions. These actions and policy interventions build on anticipated economic performance of coal units, with the most uneconomic units retiring first and others following. As in Current Measures, the Bottom-Up scenario distinguishes between deregulated markets and utilities in traditionally regulated markets. In deregulated markets, coal units are more exposed to market conditions resulting in a greater response to shifting economics, policy, and advocacy. However, we assumed that uneconomic coal units in regulated markets would also close. While coal units in regulated markets are more insulated from economic forces, local advocacy and state and federal policy drive down uncapped coal generation.

The Bottom-Up scenario assumes that in 2025, coal plants in deregulated markets that were uneconomic for 60 percent of the years modeled from 2012 retire while units in regulated fleet retire if they have been uneconomic for 75 percent of the years modeled. Our analysis assumed that 10 states do not close any units by 2025, despite poor economics and the detriment to ratepayers, due to the fact that these states have historically been more protective of coal generation in state. By 2030, our Bottom-Up scenario assumes that all Tier 1 states, except Pennsylvania, completely retire coal generation. Units in unregulated markets that were uneconomic for half of the years modeled retire and units in regulated utilities that were uneconomic for 60 percent of the years modeled retire. Furthermore, the most uneconomic units in resistant states retire some of their coal. By 2030, 77 GW of coal generation remains in service nationwide. Our model assumes that state action and grassroots advocacy is effective at cutting installed capacity and also preventing a rebound in coal generation for the remaining units such that the average capacity factor for units falls from 53 percent today to 47 percent by 2030. This reduces coal generation to 317 TWh in the Bottom-Up scenario.

The All-In scenario assumes ambitious federal policy building on state level actions starting in 2021. Building on the Bottom-Up assumptions, federal policies drive coal reductions in even the most resistant states. By 2025, capacity falls to 108 GW. By 2030, the U.S. removes all uncapped coal generation from the grid. Under this future, a small remainder of coal capacity may remain in the system through 2030, where needed for spinning reserves or seasonal system balancing, but overall generation will remain minimal and any associated greenhouse gas emissions would be captured and sequestered.

We used data from Bloomberg New Energy Finance's report "Half of U.S. Coal Capacity on Shaky Economic Footing,"[57] EIA, and Sierra Club as well as expert consultations to inform our coal generation projections.

Note: inputs for this scenario were fed directly to GCAM, rather than being modeled in ATHENA first.

GAS GENERATION

The gas generation scenarios represent the implications of increasingly competitive clean energy generation along with greater local and state-led actions targeting utilities, plant operators, and public utility commissions as well as strong policy interventions.

We developed plant-by-plant retirement assumptions for the Bottom-Up and All-In scenarios using unit-level data on the existing gas fleet (from EIA) and a new Rocky Mountain Institute (RMI) dataset of gas plants proposed for construction within the next four years.[58] The latter dataset also includes projections for the year in which the levelized cost of energy (LCOE) for a new gas plant becomes more expensive than a comparable clean energy portfolio in each state. In some states, that threshold has already been passed. We identified plausible reductions in levels of planned construction and lifetimes of the existing fleet for each tier under the Bottom-Up and All-In scenarios. For simplicity, fixed capacity factors based on turbine type were used, based on the overall capacity factors of the existing fleet.

The Bottom-Up scenario assumes a complete cessation of new gas builds in Tier 1 states due to a combination of both market competition and the ambitious mitigation goals of those states, constraints on new builds in Tier 2 states due to market competition, and business as usual new builds in Tier 3 states, even in the face of increasingly competitive clean energy projects. In Tier 2 states, only planned gas facilities that are currently economic relative to a clean energy project are assumed to be constructed. It was assumed that no new plants are built in Tier 2 states beyond those planned today. In Tier 3 states, we assume all currently planned gas plants for the next four years are constructed and that plants continue to come online through 2030 at the same rate. To create scenarios of retirement of gas plants in operation today, plant-level data of the existing gas fleet (from EIA) was employed. Age cutoffs were defined for each tier and for each of two technology categories (combined cycle and other). Existing facilities across all tiers are retired at lifetimes consistent with expected lifetimes for gas facilities (30 years for combined cycle, 43 years for others). Tier 1 and Tier 2 states retire plants slightly early, but still within expected lifetimes. Based on these assumptions, gas generation remains essentially flat through 2030.

For the All-In scenario, the assumptions were adjusted to reflect ambitious national efforts to deploy clean energy portfolios and phase out unabated fossil fuels. No new gas builds without CCUS are constructed in Tier 1 and Tier 2 states, and only new facilities that are currently economic are constructed in Tier 3 states. It was assumed that no new plants are built in Tier 3 beyond those planned today. The retirement age for existing facilities (see above paragraph) is assumed to be a little less than the historical average, but largely still within the expected lifetime of gas facilities. Based on these assumptions, gas generation without CCUS declines by approximately 20 percent by 2030 relative to current levels.

Another important element of the All-In scenario is the installation of new gas generation with CCUS. This scenario assumes that many states incorporate gas with CCUS within their energy portfolios. This leads to roughly 517 GWh of gas with CCUS in 2030, or roughly 12 percent of overall generation.

There are a number of different variables that influence the prospects for gas generation. To test the robustness of the overall generation pathways, a number of different sets of assumptions were explored, all of which lead to the same overall results. Adjustments that were explored included increasing the utilization of existing gas facilities, loosening and tightening the economic requirements for new gas builds, and increasing or decreasing the lifetime of existing gas facilities. Because states often sit within larger grid regions and frequently define clean energy portfolios based on the generation they purchase, the gas generation by state is somewhat flexible while still being consistent with the overall approach and national generation totals.

Note: The national generation pathways as well as the general character of the distribution among tiers for this scenario were fed directly to GCAM rather than being modeled in ATHENA first.

NUCLEAR

In 2018, the U.S. had 99 GW of nuclear capacity.[59] Many plants are reaching retirement age and the only new construction currently happening is the two Georgia Vogtle plants which are scheduled to come online in 2020-2021, with 2.2 GW of capacity.[60] In the past six years, about 6 GW of nuclear plants have been retired. Due to recent state policy in New York, Illinois, Connecticut, New Jersey, and Ohio, 12.7 GW that were at risk have been preserved, but 8.3 GW is still at risk of retiring in the next few years.

In the Bottom-Up scenario, we assume that several other states enact policies to preserve an additional 2.6 GW of capacity. This is approximately half of the capacity that could be feasibly saved, and could be achieved if, for example, Pennsylvania and Iowa enacted policies to preserve their nuclear plants. It results in 95 percent of U.S. nuclear generation being preserved.

In the All-In scenario, we assume that a federal clean electricity standard promotes the retention of nuclear plants and that 96 percent of nuclear generation is preserved, based in part on modeling analysis of the Clean Energy Standard Act of 2019 from Resources for the Future.[61]

OIL AND GAS METHANE

For the Bottom-Up scenario, we assume that ambitious standards to reduce fugitive methane from both upstream and downstream oil and gas systems continue to move forward. Specifically, we assume that all states with aspirational regulations currently under development are able to achieve their goal (whether they are Tiers 1, 2, or 3). Data on the impacts of current aspirational state policies were provided by EDF and range in terms of their impacts depending on emissions sources covered and the projected growth in oil and gas production activity within a given state. Beyond the achievement of aspirational regulations, we further assume that

Tier 1 and 2 states achieve minimum reductions of 60 percent by 2030, based on the impact of best-in-class comprehensive regulations currently under development. Finally, consistent with the Current Measures, the scenario assumes that most oil and gas producers maintain compliance with 2016 federal NSPS standards (OOOOa) such that 75% of the abatement that would have occurred under the 2016 rule is achieved – despite the rollbacks – due to regulatory uncertainty.

For the All-In scenario, we assume that all states achieve best in-class, comprehensive regulations, achieving minimum reductions of oil and gas methane of 60% by 2030. We further assume that by 2022, full compliance toward federal NSPS standards (OOOOa) is achieved across all jurisdictions, reflecting federal restoration of the standard.

Data on state and federal policy impacts were provided by EDF and integrated into the ATHENA modeling process by the America's Pledge analytic team.

Decarbonize End-Uses Assumptions

BUILDINGS — ENERGY EFFICIENCY

The building energy efficiency strategy highlights how local governments, real estate companies, and utilities can come together to implement new programs and policies to maximize energy savings and emissions reductions achievable through both more efficient new builds and existing building retrofits. For existing residential and commercial buildings, for example, we assume that state-level energy efficiency resource standards (EERS) lead to annual energy savings of 2 percent in Tier 1 states and 1.5 percent in Tier 2 states in the Bottom-Up scenario. These savings are then carried over to the All-In scenario as well. In addition, in the All-In scenario we assume that states (tier 1, 2, or 3) may achieve additional savings beyond Bottom-Up scenario levels, based on estimated economic savings potential by state. Estimates of economic savings potential by state were derived from analysis from Electric Power Research Institute.[62] Finally, in the All-In scenario, we also assume that funding for the federal Weatherization Assistance Program (WAP) returns to the levels seen under the American Recovery and Reinvestment Act (ARRA), resulting in a commensurate increase in energy savings of approximately 5,342,000 MMBtus nationwide each year beginning in 2022.[63] We incorporated these savings into the ATHENA model by taking the average electricity versus gas savings by home type using data from Oak Ridge National Laboratory (ORNL)[64 65 66] and weighting it by home type based on the percentage of units that were served under WAP under ARRA. These savings compound as more homes are weatherized under the program each year through 2030.

For new buildings, we assumed that under the Bottom-Up and All-In scenarios, states continue to adopt new, more efficient codes at about the rate they have historically. Since the Pacific Northwest National Laboratory's *Impacts of Model Building Energy Codes* report[67] utilized this methodology for commercial and residential codes, we used their results as our input assumptions for emissions reductions from state building code adoption. We also modeled the impact of stretch or reach codes adopted by leading cities beginning in 2022 in both the Bottom-Up and All-In scenarios. We defined leader cities likely to adopt stretch codes as major cities in Tier 1 states, including the state capital, and additional cities in Tier 1, 2, or 3 states that have demonstrated climate leadership by either having a 100 percent renewable electricity goal[68] or being a member of the Climate Mayors initiative.[69] For these cities, we assumed that – after first calculating the impact of EERS standards and buildings codes at the state level – an additional 11 percent energy savings will be achieved for the portion of each of these cities' energy demand that is from new or altered building stock each year. The share of demand that is from new/altered building stock versus existing was calculated by assuming that the annual percentage of new/altered floor space at the state level (provided by AEO) is the same at the city level within each state. The assumed average savings of 11.2 percent is the additional site energy savings attributed to New York's 2016 Stretch Code Supplement relative to ASHRAE 90.1-2013, according to a 2018 Pacific Northwest National Laboratory (PNNL) study.[70] The New Buildings Institute has a set of stretch code strategies that represent a 20 percent performance improvement for commercial buildings over the ASHRAE 90.1-2013 code (and similar savings over the IECC 2015 code),[71] and a 2017 study of Massachusetts' stretch code by NMR Group and Cadmus Group found that the code had an approximately 20 percent greater building efficiency requirement than the code based on 2009 IECC,[72] but the America's Pledge research team decided to conservatively apply the simulated New York savings as a blanket assumption for cities in all jurisdictions regardless of what the base code was in a given model year.

BUILDINGS — ELECTRIFICATION

Both the Bottom-Up and All-In scenarios model building electrification occurring across the U.S. in line with economic and market potential studies. The Bottom-Up scenario assumes that space and water heating electrify where there is greatest economic incentive and where there is stated interest. We used the National Renewable Energy Laboratory's *Electrification Futures Study* as the basis for the potential for electrified appliances.[73] Consistent with this NREL modeling and analysis, we assume Tier 1 and 2 states achieve sales penetration rates of electric appliances consistent with NREL's high electrification scenario, including 60 percent of residential space heating, 44 percent of residential water heating, 39 percent of commercial space heating, 18 percent of commercial water heating, and 42 percent of commercial cooking by 2030, while Tier 3 states achieve sales percentages in line with NREL's medium electrification scenario. For a particular group of states, including California, Florida, Georgia, South Carolina, North Carolina, Alabama, Mississippi, Louisiana, Arkansas, Tennessee, and Virginia, who are already seeing or approaching the levels of electrification projected by the NREL EFS high scenario for 2030, we assume that these states achieve 2030 sales penetration rates of electric appliances consistent with NREL's high electrification scenario for 2050, including 86 percent of residential space heating, 59 percent of residential water heating, 71 percent of commercial space heating, 40 percent of commercial water heating, and 99.5 percent of commercial cooking. For the All-In scenario, all states achieve electric appliance sales in line with NREL's high scenario due to federal appliance standards and other policies, except for the high-penetration group of states (listed above), which achieve 2030 electric appliance sales in line with NREL's high scenario projections for 2050. By 2030, most new buildings are completely electric, particularly in cities and states with restrictions or moratoria on gas infrastructure expansion, such as the recent policies requiring all-electric new buildings in Berkeley,[74] San Jose, California[75], and Brookline, Massachusetts[76]. Existing buildings are on a pathway to net zero emissions by 2050.

The modeling scenarios in this report include heat pump adoption assumptions in residential, commercial, and industrial buildings, but due to the time series captured by the model and appliance turnover limitations, their emissions impact is not fully recognized in the near-term. Space heaters, water heaters, and air conditioning units average 15-year lifetimes before they are replaced, so there is an embedded stock that will slowly phase out past the 2030 modeling window. As a result of supply and demand dynamics today, low heat pump uptake will gradually accelerate over time as costs decrease and performance increases. As electricity generation continues to get cleaner past the 2030 timeframe, electrified heating and cooling will exhibit a stronger signal in total emissions reductions. Additionally, because some modern HVAC manufacturers and installers still choose to use super-polluting HFCs as a refrigerant, phasing out HFCs plays a vital, complementary role in reducing the long-term global warming impacts associated with space conditioning.

TRANSPORTATION — VEHICLE STANDARDS AND ACCELERATED VEHICLE SCRAPPAGE

In 2016, the Obama Administration affirmed light-duty vehicle standards covering model years 2021-2025. The Trump Administration has moved forward to rollback these standards, pledging to revoke California's authority to enforce their standards, and is soon to release a rule that flat-lines the standards from 2021-2025. These actions introduce significant new uncertainty in future vehicle standards.

As discussed previously, our Current Measures scenario assumes that the compromise made between California and automakers would prevail court challenges and enter force, applicable to vehicles made between model years 2021 and 2026. For the Bottom-Up scenario, we assume that California and Tier 1 and 2 states would move forward with ambitious light-duty standards from 2026-2030 – reducing carbon dioxide emissions from new internal combustion engine (ICE) cars and light-trucks by 40 grams per mile by 2030. By 2030, new ICE cars would achieve an average 48 miles per gallon (on-road tailpipe) and light-trucks 34 miles per gallon (on-road tailpipe).

The All-In scenario assumes the Obama era light-duty vehicle standards remain enforced and in place at the original stringency through 2025. After 2025, all light-duty vehicles improve GHG performance by 40 grams per mile reaching 55 miles per gallon (on-road tailpipe) for cars and 38 miles per gallon (on-road tailpipe) for light-duty trucks by 2030. This does not include EVs, which are discussed below.

In addition to vehicle standards, the All-In scenario models the impact of federal policies aimed at removing inefficient vehicles, also known as "clunkers," from the road. Such policies would have immediate GHG benefits but also accelerate the transition to electric vehicles if designed properly. Furthermore, accelerated scrappage policies have substantial criteria pollution benefits, especially if targeting heavy-duty vehicles. To model this, we assumed that for all existing passenger and freight vehicles, the average expected lifetime is reduced from 11-20 years (depending on the weight classes) to 10 years, and that inefficient vehicles produced prior to 2010 are fully retired by 2030.

TRANSPORTATION — VEHICLE ELECTRIFICATION

In addition to improved conventional vehicle performance, we assume a swift U.S. transition toward electric vehicles. In the light-duty sector, electric vehicles rapidly outpace prior projections, driven by a combination of state programs such as rebates and emissions standards along with improving economics and falling battery costs. In the medium- and heavy-duty sectors, more and more electric vehicle options become available, and fleets invest in electric vehicles where grants and sufficient charging are available. We used the National Renewable Energy Laboratory's *Electrification Futures Study* as the basis for the potential for electrified light-, medium-, and heavy-duty vehicles and transit buses through enhanced state and federal policy, including financial incentives, charging infrastructure build-out, and utility rate reform.

Consistent with this NREL modeling and analysis, for the Bottom-Up scenario, we assume Tier 1 and 2 states pass policies and work with the private sector to accelerate electric vehicles such that EV sales achieve rates of 66 percent for light-duty cars, 56 percent for light-duty trucks, 20 percent for medium-duty trucks, and 60 percent for transit buses are achieved by 2030, in line with the EFS high scenario. For heavy-duty vehicles, we expect slightly higher sales than NREL's EFS high scenario projections (13 percent sales by 2030) due to increases in regional haul,[77] increasingly promising economics for long-haul,[78] new fuel cell commercial vehicles entering the market,[79] and proposed zero emissions sales requirements for freight vehicles,[80] assuming 15% electric sales by 2030 in Tier 1 and 2 states. For Tier 3 states, we assume sales penetration numbers in line with the NREL EFS medium scenario, including 63 percent of light-duty car, 53 percent of light-duty truck, 10 percent of medium-duty truck, 3 percent of heavy-duty, and 20 percent of transit bus sales by 2030. Sales percentages were converted into passenger kilometers traveled (for passenger vehicles) or ton-kilometers (for freight vehicles) using average annual vehicle miles traveled data from U.S. Federal Highway Administration (FHWA) Highway Statistics 2017,[81] ton-kilometer data from UC Davis[82] and weighted by the number of vehicles registered in each state tier, according to FWHA's Highway Statistics.

For the All-In scenario, federal incentives, investments in charging infrastructure, and other policies drive significant additional EV adoption. In this scenario, 66 percent of light-duty car sales, 56 percent of light-duty truck sales, 20 percent of medium-duty truck sales, and 15 percent of heavy-duty truck sales in 2030 are assumed to be EVs nationwide. By 2030, only electric buses are eligible for federal transit funding such that 100 percent of new bus sales nationwide are electric.

TRANSPORTATION — VEHICLE MILES TRAVELED

In the Bottom-Up scenario, we assume Tier 1 states that do not already have VMT goals implement smart-growth programs that reduce VMT 2 percent by 2030 relative to business as usual (BAU). These programs would include making cities more walkable and bikeable and expanding public transit. Supportive policies such as dedicated bus lanes, congestion pricing, and transit-oriented development are important for policy planning.

In the All-In scenario, we use the Enhanced Engagement scenario assumptions from the 2018 report. Nationwide, VMT are reduced 2 percent by 2025 and 3.25 percent by 2030 relative to BAU. Potential levers include federal investments in transit (e.g. FAST Act funding), tax breaks that favor transit over driving, and enabling states to toll federal highways. The impact of these interventions would be small in the near-term and grow over the long-term because changing land use patterns have a long lead time and changing congestion and parking prices can be politically difficult.

INDUSTRIAL EFFICIENCY

DOE and national lab analyses,[83] have suggested that industries that enact efficiency measures can improve both their performance and competitiveness in addition to reducing primary GHG emissions. Building on these analyses in the Bottom-Up and All-In scenario we assume that states and the federal government enact policies (via incentives and regulations) to improve industrial efficiency. For the purpose of our modeling, we assume that this takes the form of a mandatory policy requiring industrial facilities to adopt the ISO 50001 performance standard. This could be considered a proxy measure for a suite of tools and approaches.

For our Bottom-Up scenario, Tier 1 states rapidly scale this policy such that by 2030, 75 percent of industrial businesses are required to adopt ISO 50001 energy efficiency protocols. Tier 2 states adopt this policy but only target half of industrial facilities in their state, while Tier 3 states apply the standard to 10 percent of industrial facilities. We assume that adoption of ISO 50001 results in a 5 percent efficiency gain in the first year of implementation and an additional 1 percent every year after that.[84]

The All-In scenario builds on Bottom-Up leadership on industrial efficiency, extending the policy to all 50 states – with the application accelerating post-2025 such that by 2030, 100 percent of industrial companies nationally have adopted ISO 50001.

INDUSTRIAL CCUS

In 2018, via Section 45Q, Congress passed new tax incentives for CCUS. States can help translate these federal incentives into industrial mitigation. A recent study by the Energy Futures Initiative (EFI) estimates that between 50-100 MMT CO_2e could be sequestered due to 45Q alone.[85] With additional policy support, the potential across industry and the power sector could be much higher. However, given uncertainty and the time it will take to scale the industry, we estimated that states promote industrial CCUS such that by 2030, 50 MMT CO_2e would be sequestered. We assume the same potential for Bottom-Up and All-In scenarios.

INDUSTRIAL ELECTRIFICATION

In addition to industrial efficiency and CCUS, there is potential to reduce industrial emissions by switching from fossil-based fuels used to power industrial equipment to clean electricity. In the Bottom-Up scenario, we apply the technology adoption assumptions from NREL's Electrification Futures high case scenario to Tier 1 and 2 states, which translates to electrified technologies making up 42 percent of new process heat sales, 25% of new curing equipment sales, and 22% of new space heating sales, 13% of new drying equipment sales. For Tier 3 states, we apply the technology adoption assumptions from NREL's Electrification Futures medium case scenario, which translates to electrified technologies making up 27% of new process heat sales, 10% of new curing equipment sales, 13% of new space heating sales, 5% of new drying equipment sales, and 0% of new boiler sales by 2030.

In the All-In scenario, federal policies drive industrial electrification in all 50 states consistent with NREL's Electrification Futures high case scenario, achieving a net decrease in energy consumption from industrial processes of 118 TBtu by 2030, while also increasing electricity share by 60 TBtu.

INDUSTRIAL BUY CLEAN

Finally, for the Bottom-Up and All-In scenarios, we model a policy representing the impact of state and federal policies on reducing emissions from cement. Policies such as a "Buy Clean" government procurement policy that uses the power of government purchasing to reduce embodied emissions in infrastructure inputs, such as iron/steel and cement, are gaining popularity globally and are considered a potentially effective tool to decarbonize the industrial sector. Using analyses from EFI,[86] McKinsey,[87] and IEA,[88] we estimated the potential to reduce cement emissions through materials efficiency and fuel switching. For the Bottom-Up scenario, we assume that Tier 1 states would reduce cement emissions 22 percent from 2018 levels by 2030. For the All-In scenario, we assume that a federal policy places additional requirements on Tier 2 and 3 states such that all states achieve the equivalent to a 20 percent reduction from 2018 levels by 2030. Due to modeling constraints, we did not include iron and steel in our Buy Clean assumptions, but current Buy Clean policies do apply to these sectors.

HYDROFLUOROCARBONS

States are in the process of adopting rules to replace HFCs with safer alternatives, stepping forward to fill the current gap at the federal level. The U.S. Climate Alliance (USCA), a coalition of state governors totaling 25 in number at the time of the writing of this report, announced its commitment to reduce short-lived climate pollutants in 2018, including through the adoption of HFC rules at the state level. As discussed under Current Measures, California, Vermont, and Washington have adopted such rules, with additional proposed legislation currently under discussion in other states. Collaborative campaigns involving states, cities, and supermarket chains can further encourage additional commitments across the supermarket industry, one of the largest users of refrigerants.

For the Bottom-Up scenario, we assume that Tier 1 and 2 states follow the lead of California, Washington, and Vermont by adopting SNAP programs that are expanded to include aerosols as well as refrigerants. The projected impacts of these programs are derived from analysis published by the California Air and Resources Board (CARB), described in the *Assessing The Impact of Current Policies and Commitments* section of this chapter, and result in reductions of up to 40 percent by 2030 at the state level. We also assume that at the business level, by 2030 50 percent of U.S. supermarkets achieve leakage reductions from refrigeration equipment in-line with average reduction levels currently achieved by EPA GreenChill partners.

For the All-In scenario, we assume that all states achieve a reduction in HFC emissions of 40 percent by 2030 from 2013 levels, in-line with current best-in class, proposed state level regulations as well as the impact of federal ratification of the Kigali Amendment. Projected impacts of these policies were derived from analysis conducted by CARB.[89]

Assumptions regarding the additionality of these policies and their overlap with other mitigation polices in this sector – both subnational and federal – followed the same logic as described in *Assessing the Impact of Current Policies and Commitments* section.

BIOFUELS

Under both the Bottom-Up and All-In scenarios, we assume that the production and use of cellulosic biofuels and biodiesel continues to grow at historic rates of 30 percent and 10 percent annually, respectively. We also assume that the production and use of advanced biofuels such as sustainable aviation fuel (SAF) grows approximately two percent each year as new production facilities come online[90] and leading Tier 1 states and cities work with their large hub airports to encourage the blending of SAF with traditional jet fuel to achieve a 10 percent HEFA blend by 2030. Using data on jet fuel consumption by state[91], and enplaned passengers per airport[92], we approximated jet fuel consumption per large hub airport to inform our advanced biofuels projections. We checked our biofuel production projections for consistency with the $60/ton base case of the 2016 Billion-Ton Report[93].

Enhance Ecosystems Assumptions

LAND USE

For the Bottom-Up scenario we assume that states implement programs to promote conservation, restoration, and improved land management. Nature 4 Climate has identified the state-by-state additional mitigation potential of 11 natural climate solutions: reforestation, avoided forest conversion, cover cropping, fire management, urban reforestation, avoided grassland conversion, grassland restoration, ally cropping, cropland nutrient management, improved manure management, and improved rice cultivation.[94] We assume that California, which has its own goals for natural and working lands, achieves -40 metric tons of CO_2e, and other Tier 1 States achieve 60 percent of additional mitigation potential of these natural climate solutions at $10/ton by 2030. Tier 2 states achieve 30 percent of their potential. Combined, this is a total increase in the land sink of 79 metric tons of CO_2e in 2030.

For the All-In scenario, we assume there are federal investments in reforestation and soil carbon sequestration. California achieves -40 metric tons of CO_2e by 2030. All other states achieve 60 percent of additional mitigation potential of the natural climate solutions at $10/ton by 2030 (full potential achieved by 2050 with longer time period resulting from delays in reaching landowners and institutions that are hard to reach). Combined, this is a total increase in the land sink of 167 metric tons of CO_2e in 2030.

Cross-Cutting

CARBON PRICING AND GHG TARGETS

An increasing number of states are adopting ambitious GHG reduction targets that vary in terms of stringency. States such as California have a now long-standing track record of achieving near-term benchmarks toward long-term goals and incorporating legally enforceable limits into policy. Other states have recently adopted more aspirational goals through executive orders or through the adoption of resolutions codified in signed legislation.

To model the impact of state level GHG target achievement, in the Bottom-Up scenario we assume that twelve states (in addition to California) that have GHG targets codified in legislation fully achieve their goals by 2030 (or for goals where the target year is after 2030, we assume that states achieve linear progress toward these goals from the target base year through 2030). We also assume that six states with more aspirational goals (e.g. those promulgated through executive orders but not yet codified in legislation) achieve 75 percent of their goals by 2030 (or are on track to meet 75 percent of the goal if the target year is after 2030).

For the All-In scenario, we assume that complimentary federal policy allows for the achievement of all binding and non-binding state level GHG targets. In other words, all 19 states with targets (including California) fully achieve their targets by 2030 (or are on track to fully achieve their targets if the target year is after 2030).

OTHER METHANE AND NITROUS OXIDE

In the Bottom-Up scenario, we assume that states regulate methane and nitrous oxide and put in place incentives to promote biodigesters to reduce methane emissions. All states achieve the non-CO_2 mitigation that is cost effective but do not achieve any mitigation that has marginal costs. To calculate this, we apply EPA's non-CO_2 marginal abatement cost curves.[95] We assume 100 percent of the non-CO_2 mitigation potential at $0/ton or less is achieved by all states for livestock, landfill, coal mining, nitric and adipic acid, and croplands.

In the All-In scenario, we assume that federal regulations are put in place to limit methane and nitrous oxide and strong incentives promote the use of biodigesters. All states achieve 100 percent of the potential for non-CO_2 mitigation at $100/ton or less for livestock and $30/ton for landfill methane, coal mining, croplands, and nitric and adipic acid. While the same modeling approach was taken for these non-CO_2 sources, the measures that will be taken to address them vary. In the report, we categorized non-CO_2 emissions from coal mining into Principle 1 (Accelerate Toward 100 percent Clean Electricity and Other Energy Supplies), nitric and adipic acid into Principle 2 (Decarbonize End Uses), and livestock, landfill, and croplands into Principle 3 (Enhance Ecosystems).

Estimating Overall National GHG Implications Using Scenarios in GCAM-USA

An important step in the analysis was the development of estimates of the overall, economy-wide emissions implications of the three scenarios in this study: the Current Measures scenario, the Bottom-Up scenario, and the All-In scenario. This section discusses the process of developing these economy-wide estimates.

OVERVIEW OF GCAM-USA

The estimates of economy-wide emissions results in *Accelerating America's Pledge* are based on a version of the Global Change Assessment Model (GCAM) with detailed representation of the U.S. energy system at the state level (GCAM-USA). The global version of GCAM is a multi-sector model that represents the energy and economic systems for 32 geopolitical regions, including the United States. GCAM represents land use and agriculture in 384 land regions nested within 235 water basins. GCAM tracks emissions of a range of GHGs and air pollutants from energy, agriculture, and land use systems.

GCAM-USA is a version of GCAM that represents the energy and economy components of the U.S. for all 50 states and the District of Colombia while maintaining the same level of detail in the rest of the world. GCAM-USA was the primary modeling tool used in the U.S. Mid-Century Strategy and was used in the 2018 report, *Fulfilling America's Pledge*.

The energy system formulation in GCAM-USA consists of detailed representations of depletable primary resources such as coal, gas, oil and uranium, in addition to renewable resources such as bioenergy, hydro, solar, wind and geothermal. Bioenergy production is modeled at a subnational level in the agriculture and land use module that determines the allocation of land to competing uses such as food crops, commercial biomass, forests, pasture, grassland, shrubs, desert, tundra, and urban land.

GCAM-USA also includes representations of the processes that transform these resources to final energy carriers. These energy carriers, in turn, are used to deliver services to end users in the buildings, transportation, and industrial sectors. GCAM-USA includes representations of energy demand for every region included in the model. Building and transportation sectors are modeled with substantially more detail than the industrial sector. Key energy conversion sectors such as refining and electric power are modeled at the state-level. The electric power sector includes representations of a range of power generation technologies including those fueled by fossil fuels (with and without CCUS), renewables, bioenergy (with and without CCUS) and nuclear. Future improvements in technological costs and performance are inputs to the model and are represented through decreasing costs and increasing efficiencies over time.

GCAM-USA is a market equilibrium model. The market equilibrium in each period in GCAM-USA is solved by finding a set of market prices such that supplies and demands are equal to one another – "in equilibrium" – in all markets as the actors in the model adjust the quantities of the commodities they buy and sell[96]. Choices about levels of energy use, technologies, and fuels are based on relative costs of these various options. In GCAM-USA, these choices are developed using what is referred to as "discrete choice" formulation. In a discrete choice formulation, actors respond to prices of different choices by adjusting the balance among these choices rather than selecting a single option. GCAM operates in 5-year time-increments, with each new period starting from the conditions that emerged in the last.

IMPLEMENTING THE THREE SCENARIOS IN GCAM

State, city, and business actions affecting energy-related CO_2 emissions were incorporated into the economy-wide analysis in *Accelerating America's Pledge* by directly altering inputs to GCAM-USA. Outputs from the sectoral analysis were converted to GCAM-USA inputs. In these instances, sectoral impacts were converted into metrics (See Table 6) that can drive sector reductions in GCAM-USA. As a technical approach to handle the "hand-off", most sectoral metrics were aggregated up to the state level for inclusion in GCAM-USA (Table 6). However, for some policies – GHG targets and renewable energy targets – the impacts were applied at the electricity grid region to allow for better consideration of the interactions among states. For technical reasons, several policies (e.g., freight electrification and accelerated scrappage) were applied at the national level even for the Bottom-Up scenario and did not fully follow the tier structure for that scenario.

Table 6 | Converting ATHENA outputs to GCAM inputs

	AGGREGATED ATHENA METRIC	GCAM INPUT METRIC	GCAM GEOGRAPHIC LEVEL
GHG targets	MT CO_2e cap	MT CO_2e cap	Grid region
Renewable energy mandates and targets	TWh RE demand	% renewable of total electricity load	Grid region
Energy efficiency measures	TWh electricity and BCF gas saved by sector (residential, commercial, and industrial)	TWh electricity and BCF gas saved by sector (residential, commercial, and industrial)	State level
Vehicle miles traveled reduction targets	VMT reduced	% below GCAM baseline	State level
Electric vehicle mandates and targets	ZEV sales	# electric vehicle miles traveled and # electrified freight ton-miles	State level
HFC emissions mitigation measures	MT CO_2e HFC emissions abatement	% below EPA baseline	State level
Oil and gas systems methane mitigation measures	MT CO_2e CH_4 emissions abatement	% below updated baseline (AEO growth rate with EDF emissions factors)	State level

Note: This step is necessary to enable the aggregated sectoral impacts from ATHENA to be incorporated in the economy-wide, all-GHG modeling framework of GCAM-USA.

Emissions trajectories and policies targeting several important categories of greenhouse gas emissions were calculated outside of GCAM-USA. These included CH_4 emissions from oil and gas systems, coal mining, landfills, and livestock; N_2O emissions from croplands, livestock, and nitric and adipic acid production; and emissions of F-gases including HFCs. Because GCAM's non-CO_2 emissions inventory is based on the Emissions Database for Global Atmospheric Research (EDGAR), it differs from the inventories used in U.S. government analyses, including EPA inventories and the Biennial Report. Non-CO_2 projections in GCAM-USA also differ from those published by the EPA and in the Biennial Report. For this reason, and for consistency, GCAM's non-CO_2 emissions outputs for 2005, 2010, and 2015 were normalized to historical values from the latest EPA inventory, and future emissions were scaled by the 2015 normalization factor. However, because recent research suggests that oil and gas CH_4 emissions are approximately 60 percent higher than EPA inventories, emissions for CH_4 were taken from EDF.[97] Reference future emissions were scaled using EDF emissions factors and activity factors from EIA's AEO. Finally, because of the wide range of different estimates and uncertainty in its future trajectory, the CO_2 captured in U.S. land sinks was calculated entirely outside of GCAM-USA.

For the Current Measures scenario, we assume full compliance with all binding policies but do not include pledged actions that are not yet implemented in policy. The modeling of the Current Measures scenario therefore includes only the impacts from the existing actions category from the sectoral analysis described in the *Assessing the Impact of Current Policies and Commitments* section. Additional impacts from currently pledged, aspirational commitments and policies are included in the modeling of Bottom-Up and All-In scenarios, along with the full suite of high ambition measures described in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section. Table 6 below shows the types of policies and actions modeled at various levels of ambition in each of the three scenarios. The Bottom-Up and All-In scenarios include the increased ambition assumptions articulated in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section. Other trends beyond just these policies (e.g. improvements in technology cost and performance, economic growth, population growth), are also captured in the assessment.

Table 7 | Policies reflected in GCAM-ATHENA integrated modeling

POLICY AREA	POLICIES REFLECTED IN GCAM-ATHENA INTEGRATED MODELING OF CURRENT MEASURES
GHG targets	Economy-wide GHG target (S), RGGI (S)
Renewables	RPS (S), RE target (C), RE target (B), ITC/PTC (F)
Building & industry energy demand	EERS (S), EE target (C), Building codes (F,S), Appliance Standards (F)
Transportation	ZEV mandate (S), municipal fleet target (S,C), VMT target (S,C), CAFE (F)
HFCs	SNAP (S), CA refrigerant mgmt. standards (S), Reductions reported through GreenChill program (B), Refrigerant management standards (F,S)
Oil & gas systems	Existing equipment standards (S), Reductions reported through GasStar program (B), New Source Performance Standards (F), Bureau of Land Management Rules (F)

Note: The combination of GCAM and ATHENA explicitly included these policy areas. Other trends, such as decreasing renewable costs, or coal power retirements, are also included in the analysis but are not explicitly linked to specific policies. F = Federal policies; S = State policies; C = City policies; B = Business actions. Note: these policy categories are germane to this phase of the modeling. For a more detailed view of which policies and targets are included in other parts of the quantitative assessment, refer to previous sections of this technical appendix.

For the purposes of developing an estimate of how actions in the three scenarios reduce future emissions from what would otherwise occur, we created a counterfactual reference scenario in which a range of different measures were removed from the GCAM-USA runs. This counterfactual scenario – represented in the "economic growth" bar in Figures ES-1 in *Accelerating America's Pledge* is designed to simulate the rate of emissions growth if the specific policies assessed in this report had not been implemented. This is not a comprehensive assessment of what the future might look like if states, cities, and businesses were not to have taken any actions both in the history and in the future. Doing so would require a more comprehensive analysis and accounting of all the actions that have taken place to date, which is well beyond the scope of this analysis. It would also entail challenges in removing historical policies that are embedded in parameters of GCAM-USA.

Specifically, compared to the Current Measures scenario, the counterfactual reference scenario does not include the following policies: GHG targets, RPS targets, energy efficiency targets, VMT targets, ZEV targets, HFC emission standards, and methane reduction policies in oil/gas/landfill/agriculture, as well as accelerated retirement of coal power. This reference scenario is largely the same as the GCAM-USA data used to harmonize with the ATHENA reference scenario, but the two scenarios have one major difference in the treatment of the new coal power deployment. The latter does not model new coal plants (as the coal retirement schedule is modeled independently as discussed in the *Inputs and Assumptions for Bottom-Up and All-In Scenarios* section) while the former does model new builds where market conditions allow.

CORE ASSUMPTIONS AND SENSITIVITY ANALYSES

In addition to the sectoral implications of state, city, and business actions, the results in *Accelerating America's Pledge* depend on many assumptions about how the U.S. and the world might evolve in the future. This includes, among many others, assumptions about economic activity, population growth, energy technologies like photovoltaic cells, batteries, and EVs, fossil fuel prices, and the degree to which natural lands in the U.S. are sequestering carbon. The main results in *Accelerating America's Pledge* are based on a core set of assumptions for these drivers that represents a reasonable estimate of future trends (Table 8). When results from a single scenario are presented in *Accelerating America's Pledge*, they are based on these core assumptions.

We cannot, however, fully predict any of these future trends; a range of future trends could be considered plausible. In addition, models are themselves simplifications of a complex reality and can therefore never precisely incorporate or represent all the actors and interactions that influence how the future might unfold. For these reasons, estimating future GHG emissions cannot be considered a precise exercise. To help inform the possible range of outcomes and contextualize the results, we generated a range of sensitivity assumptions for important drivers and recalculated emissions based on these new assumptions (Table 8). Three sensitivities were taken as the focus of this exercise: population and economic growth, fossil energy prices, and the nature of the U.S. land use sink. While these sensitivities are not a full representation of all factors that might influence the aggregate implications of city, state, and business actions, they nonetheless provide insight into the range of possibilities and the level of certainty associated with the projections in *Accelerating America's Pledge*. For comparison, these assumptions and sensitivities are compared in Table 8 against those in the AEO from the U.S. Energy Information Administration and the BNEF NEO[98].

Table 8 | Core Assumptions and Sensitivities for Integrated Assessment Analysis

DRIVERS	SCENARIO ASSUMPTIONS	SENSITIVITY	AEO 2019 COMPARISON	BNEF NEO 2019 COMPARISON
Economic Growth	Overall GDP[1] growth at 1.9%/year	1.4%/year (low growth) 2.4%/year (high growth)	1.8%/year (reference) 1.2%/year (low growth) 2.2%/year (high growth)[6]	1.7%/year
Population Growth	Overall population[2] growth at 0.66%/year	0.56%/year (low growth) 0.86%/year (high growth)	0.65%/year (reference) 0.52%/year (low growth) 0.76%/year (high growth)[7]	0.66%/year
Fuel Prices	Oil prices grow 2.6%/year	1.4%/year (high resources) 3.6%/year (low resources)	2.4%/year (reference) 1.9%/year (high oil/gas) 3.0%/year (low oil/gas)[8]	-
	Gas prices grow 1.8%/year	0.6%/year (high resources) 2.8%/year (low resources)	2.0%/year (reference) 0.9%/year (low oil/gas) 4.3%/year (high oil/gas)[9]	2.0%/year
Land Use	Terrestrial carbon sink assumed to be largely unchanged relative to today	+/- 170 MT CO_2e[5]	-	-
Electric Vehicles	EV percentage of LDV sales in 2030: Current Measures: 11% Bottom Up: 61% All In: 62%	Modeled as explicit policy measures	EVs make up 9.3% of LDV sales in 2030[10]	EVs make up 31.6% of LDV sales in 2030
Solar Power	Solar PV costs[3] drop 20% to $850/kW-DC by 2030 (Current Measures); 37% (All-In)	No Sensitivity	PV costs drop 13.8%[11]	Solar PV costs drop 37.1% by 2030

Table 8 | Core Assumptions and Sensitivities for Integrated Assessment Analysis (continued)

DRIVERS	SCENARIO ASSUMPTIONS	SENSITIVITY	AEO 2019 COMPARISON	BNEF NEO 2019 COMPARISON
Wind Power	Wind turbine (class 5)[4] costs drop 18% to $1,225/kW by 2030 (Current Measures); 25% (All-In)	No Sensitivity	Wind turbine costs drop 9.6%[12]	By 2030, wind costs drop:[14] 15.6% (low) 12.4% (mid) 25.6% (high)
Coal Power Plant Retirements	4%/year of capacity is retired	Modeled as explicit policy measures	3.4%/year (reference) 3.5%/year (high growth) 3.7%/year (low growth)[13]	6.3%/year

Note: All future growth rates are average year-on-year growth rates for 2020 to 2030, unless otherwise noted.

1 For comparison, the Congressional Budget Office projects 1.8% GDP growth [www.cbo.gov/publication/55551]

2 For comparison, the U.S. Census Bureau projects 0.66% population growth [www.census.gov/data/tables/2017/demo/popproj/2017-summary-tables.html]

3 Solar assumptions: Current Measures follows NREL ATB 2019 Mid Technology Cost Scenario, All-In follows NREL ATB 2019 Low Technology Cost Scenario

4 Wind assumptions: Current Measures follows NREL ATB 2019 Mid Technology Cost Scenario, All-In follows NREL ATB 2019 Low Technology Cost Scenario

5 Sensitivities in land use are based on the 2016 US Biennial Report calibrated to the latest emissions numbers and adjusted create symmetric sensitivity bounds.

6 AEO 2019, Table: Macroeconomic Indicators

7 AEO 2019, Table: Petroleum and Other Liquids Prices (Brent spot price)

8 AEO 2019, Table: Macroeconomic Indicators

9 AEO 2019, Table: Natural Gas Supply, Disposition and Prices (Henry hub spot price)

10 AEO 2019, Table: Light-Duty Vehicle Sales by Technology Type (Electric and Plug-In Electric Hybrid)

11 AEO 2019, Levelized Cost and Levelized Avoided Cost of New Generation Resources, Tables A1a, B1a (Levelized Capital Cost) - Percent change is interpolated from 2021 and 2040 data

12 AEO 2019, Levelized Cost and Levelized Avoided Cost of New Generation Resources, Tables A1a, B1a (Levelized Capital Cost) - Percent change is interpolated from 2012 and 2040 data

13 AEO 2019, Table: Electricity Generating Capacity

14 Low, mid, and high refers to the range of capacity factors. Costs for mid-capacity factor wind are expected to drop most rapidly from 2020-2030.

Socio-Economic Analysis Methodology

THE ECONOMIC BENEFITS OF AIR POLLUTION REDUCTIONS FROM POWER GENERATION

For Chapter 4 of *Accelerating America's Pledge*, we used the EPA's Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)[99] to calculate the economic benefits from air pollution reductions in the power sector in the All-In scenario. COBRA compares changes in air pollution between a control scenario and a baseline emissions scenario (years 2017 or 2025). Using a source-receptor matrix air quality model, COBRA takes changes in primary pollutants [e.g. ammonia (NH_3), nitrogen oxides (NOx), fine particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), and volatile organic compounds (VOCs)] and then generates corresponding changes in ambient $PM_{2.5}$ at the county-level. Using a range of health impact functions, COBRA then translates the ambient $PM_{2.5}$ changes into changes in the incidence of human health effects. Finally, the model monetizes the health effects. The model calculates the economic benefits from changes in:

- Adult and infant mortality;
- Non-fatal heart attacks;
- Respiratory-related and cardiovascular-related hospitalizations;
- Acute bronchitis;
- Upper and lower respiratory symptoms;
- Asthma-related emergency room visits;
- Asthma exacerbations;
- Minor restricted activity days (i.e., days on which activity is reduced, but not severely restricted); and
- Work days lost due to illness.

For our analysis, we calculated changes in air pollution in 2030. We used 2025 as the base year in COBRA (as opposed to 2017), so that in 2030 the population, baseline emissions, and incidence data assume to remain constant. For the All-In scenario by 2030, essentially all uncapped coal generation is retired. Under the All-In scenario, essentially all 259 coal plants that were operational in 2018 will be retired by 2030. To calculate the changes in air pollution in 2030 for the All-In scenario, we assumed that under a business-as-usual case, the plants would have the same output as in 2017, using data from the US Energy Information Agency (Form 860).[100] We then used emission factors for each specific coal plant from EPA's 2016 Emissions & Generation Resource Integrated Database (eGRID),[101] allowing us to calculate avoided emissions for SO_2 and NOx for each plant unit. (eGRID does not provide emission factors for primary $PM_{2.5}$). Since COBRA operates at the country-level, we then aggregated emission changes for each county in the U.S. (excluding Alaska and Hawaii). We adjusted the baseline SO_2 emissions in 2025 to account for SO_2 control technologies that may not be represented in the eGRID database. We used a database from the EPA's Air Markets Program[102] to adjust SO_2 for plants that had emission controls added between 2013 and 2017. We assumed SO_2 emissions for those plants in 2025 would equal that in 2017, under business-as-usual.

To account for changes in gas generation, which has a smaller impact on human health than coal, we used the state-level outputs from GCAM to allocate changes in gas generation in 2030 on a *pro rata* fashion to every gas plant in the eGRID database. We used generation and emission factors from eGRID for 2016, and we assumed under a business-as-usual scenario, the plants' outputs and emissions in 2030 would remain constant. Next, we aggregated the emissions changes at the county-level. We then combined the above two datasets on coal and gas generation and inputted them into COBRA.

Table 9 **Total National Health Benefits Due to Changes in Fossil-Fuel Power Generation under the All-In scenario in 2030 compared to business-as-usual (EPA's COBRA model)**

BENEFIT	VALUE
Total Health Benefits (low estimate)	$25,627,027,495
Total Health Benefits (high estimate)	$57,862,068,414
Mortality (low estimate) (avoided deaths)	2,540
Mortality (low estimate) ($)	$25,270,956,903
Mortality (high estimate) (avoided deaths)	5,744
Mortality (high estimate) ($)	$57,151,381,308
Infant Mortality (avoided deaths)	5
Infant Mortality ($)	$51,082,865
Nonfatal Heart Attacks (low estimate)	321
Nonfatal Heart Attacks (low estimate) ($)	$42,874,136
Nonfatal Heart Attacks (high estimate)	2,981
Nonfatal Heart Attacks (high estimate) ($)	$397,490,650
Hospital Admits, All Respiratory	767
Hospital Admits All Respiratory Direct	545
Hospital Admits, Asthma	66
Hospital Admits, Chronic Lung Disease	155
Hospital Admits, All Respiratory ($)	$23,991,607
Hospital Admits, Cardiovascular (except heart attacks)	933
Hospital Admits, Cardiovascular (except heart attacks) ($)	$40,567,257
Acute Bronchitis	3,541
Acute Bronchitis ($)	$1,927,427
Upper Respiratory Symptoms	64,703
Upper Respiratory Symptoms ($)	$2,438,173
Lower Respiratory Symptoms	45,184
Lower Respiratory Symptoms ($)	$1,076,266
Emergency Room Visits, Asthma	1,285
Emergency Room Visits, Asthma ($)	$614,528
Minor Restricted Activity Days	1,739,813
Minor Restricted Activity Days ($)	$134,518,479
Work Loss Days	293,410
Work Loss Days ($)	$52,597,641
Asthma Exacerbation	66,952
Asthma Exacerbation ($)	$4,382,213

STUDIES ON THE COSTS OF DEEP DECARBONIZATION IN THE UNITED STATES

In Chapter 4 of the report, the section on investments and innovative finance cites that studies on the costs of deep decarbonization in the United States generally find costs of less than 2% of GDP. Table 9 below lists these studies. Increased investment costs are at least partially offset by fuel savings. Moreover, a discussion of costs should also consider the costs of inaction on climate change, which as a percentage of GDP, can be substantial (as described in Chapter 4 of the report in the text box *The Costs of Waiting*).

Table 10 | Deep Decarbonization Studies

SOURCE	COST OF DEEP DECARBONIZATION	SCENARIO
Williams et al. (2015)[103]	$90 billion savings (-0.2% of GDP) to $730 billion costs (1.8% of GDP)	80% emissions reduction by 2050
Risky Business[104]	A mixed resources scenario would increase annual economy-wide investment as a percentage of GDP by 0.4 to two percent over the period 2020-2050. From 2020 to 2030, and additional capital investment of $220 billion per year would be needed. This would be offset by fuel savings of $70 billion per year from during this period	80% emissions reduction by 2050, mixed renewables scenario
NRDC[105]	Costs 1% more than current U.S. energy costs, but would be outweighed by a factor of 7 by the environmental and social benefits	80% emissions reduction by 2050
Union of Concerned Scientists[106]	New capital investments in the electricity sector will require $250 billion per year from 2016-2033, 3-4 times more than the reference case	Emissions 90% or more below 2005 levels by 2050
Asia-Pacific Economic Cooperation[107]	An additional $2.6 trillion will be needed for capital investments from 2017-2050 compared to business-as-usual, but that fuel savings over this period will be $5.5 trillion	2°C scenario
Evolved Energy Research[108]	Net system costs less than 2% of the forecast GDP in 2040 (approximately $600 billion), which is within the historical range for energy spending in the US	Scenarios with CO_2 concentrations at 350 parts per million
Boston Consulting Group[109]	Net annual investments of 1.5% of GDP from 2015 to 2050 (cumulatively, $13.6 trillion), though not compared to baseline without climate action	2°C scenario

Appendix A:
Detailed Summary Tables for Sectors and Scenarios

OVERVIEW

The following section summarizes sector-specific assumptions and outputs for each of the scenarios.

Table 11 | **Full set of sector-specific modeling and policy assumptions for the three scenarios**

PRINCIPLE 1 ACCELERATE TOWARD 100% CLEAN ELECTRICITY	SCENARIO	DESCRIPTION OF SCENARIO ASSUMPTIONS
Power	Current Measures	Federal wind and solar incentives through 2020/2022; states achieve binding RPS targets, including new policies enacted in 2018-2019. All announced coal plant retirements occur as scheduled; an additional share of uneconomic coal units located in deregulated markets retire and coal generation falls to approximately 15% of total generation in 2030. 12.7 GW of at-risk nuclear capacity does not close because of existing policy actions in NY, IL, CT, NJ, OH. 8.3 GW of other at-risk capacity retires. U.S. adds 2.2 GW of new capacity in 2020-2021.
	Bottom-Up	Tier 1 states increase the ambition of their clean electricity standards achieving 60% renewable by 2030; Tier 2 states achieve 40% renewable by 2030; Tier 3 states achieve 20% renewable at a minimum; states, cities, and utilities also achieve all currently pledged renewable energy commitments. Tier 1 states phase out coal generation by 2030 and other states retire coal plants and constrain coal generation such that coal generation falls to 7% of national generation by 2030. Several states enact policies to preserve ~2.6 GW of the 8.3 GW of at-risk nuclear capacity that has not yet been preserved. Note 3 GW of the 8.3 GW cannot be feasibly saved, and we assume that of the remaining amount, half is saved.
	All-in	Power sector mandates, such as a clean electricity standard and other supporting policies, achieve 76% clean generation nationwide by 2030, including gas with CCUS and nuclear. Clean electricity standard and/or other policy drives coal generation down to 0 by 2030 and CCUS on coal and gas is removing 160 MMT CO_2 by 2030.
Oil and Gas Methane	Current Measures	Current federal regulations limiting fugitive emissions from new and upgraded sources (New Source Performance Standards) are achieved at an assumed coverage rate of 75%. Current state-level regulations limiting fugitive emissions from new and existing sources are achieved.
	Bottom-Up	Current federal regulations limiting fugitive emissions from new and upgraded sources (New Source Performance Standards) are achieved at an assumed coverage rate of 100% in Tier 1 and Tier 2 states and 75% in Tier 3 states. Aspirational state-level regulations limiting fugitive emissions from new and existing sources are achieved. Oil and gas companies achieve pledged commitments to reduce fugitive emissions.
	All-in	Aspirational federal regulations reducing fugitive emissions from new and existing sources are adopted and enforced.

PRINCIPLE 2 DECARBONIZE END-USES	SCENARIO	SCENARIO ASSUMPTIONS
Buildings	Current Measures	States achieve all binding Energy Efficiency Resource Standard (EERS) policies.
	Bottom-Up	Annual EERS savings of 2% achieved in Tier 1 states and 1.5% in Tier 2 states. States continue to adopt more efficient building codes at historic rates. Leading cities adopt stretch codes, resulting in an additional 11.2% energy savings for their new and altered residential and commercial building stock. Cities also achieve all pledged energy efficiency commitments. California and southeastern states with existing high levels of electrification achieve electric appliance sales shares of 86% of residential space heating, 59% of residential water heating, 71% of commercial space heating, 40% of commercial water heating, and 99.5% of commercial cooking by 2030. For all other Tier 1 & 2 states, 60% of residential space heating, 44% of residential water heating, 39% of commercial space heating, 18% of commercial water heating, and 42% of commercial cooking sales are electric by 2030. Remaining Tier 3 states see electric appliance sales as follows for 2030: 49% of residential space heating, 40% of residential water heating, 24% of commercial space heating, 7% of commercial water heating, and 33% of commercial cooking.
	All-In	Federal funding for Weatherization Assistance Program commensurate with levels under ARRA beginning in 2022. California and southeastern states achieve electrification rates in Bottom-Up scenario. For all other states, 60% of residential space heating, 44% of residential water heating, 39% of commercial space heating, 18% of commercial water heating, and 42% of commercial cooking sales are electric by 2030.
Transportation	Current Measures	California and 10 states achieve ZEV mandate targets for electric vehicle sales through 2025. California, Vermont, and Washington achieve currently on-the-books VMT reduction targets. All automakers adopt California's vehicle standard compromise reducing new light-duty vehicle emissions by 3.7% per year through 2025. This is slightly lower ambition than the Obama era LDV standards which the Trump Administration is in the process of rolling back. Obama era heavy-duty vehicle standards remain in place.
	Bottom-Up	All states adhere to California compromise through 2026 as discussed above. For Tier 1 & 2 states, 67% of light-duty car (38% BEV and 29% PHEV) and 56% of light-duty truck sales (28% BEV and 28% PHEV) are plug-in while 20% of medium-duty, 15% of heavy-duty, and 60% of bus sales are electric by 2030. For Tier 3 states, 63% of light-duty car (30% BEV and 33% PHEV) and 53% of light-duty truck sales (19% BEV and 34% PHEV), 10% of MDV, 3% of HDV, & 20% of bus sales are electric by 2030. California and Tier 1 and 2 states move forward with ambitious light-duty standards from 2026-2030 – reducing carbon dioxide emissions from internal combustion engine (ICE) cars and light-trucks by 40 grams per mile by 2030. By 2030, new ICE cars achieve an average 48 miles per gallon (on-road tailpipe) and light-trucks 34 miles per gallon (on-road tailpipe). Tier 1 states that do not already have VMT goals implement smart-growth programs that reduce VMT 2% by 2030 relative to BAU. Cities also achieve all pledged VMT reduction commitments. Cellulosic biofuels grow 30%, biodiesel grows 10%, and advanced biofuels grow 2% annually through 2030.
	All-In	Nationwide, 67% of light-duty car and 56% of light-duty truck sales are plug-in while 20% of medium-duty, 15% of heavy-duty, and 100% of bus sales are electric by 2030. Obama era light-duty vehicle standards remain in force and in place at the original stringency through 2025. After 2025, all light-duty vehicles improve GHG performance by 40 grams per mile, reaching 55 miles per gallon (on-road tailpipe) for cars and 38 miles per gallon (on-road tailpipe) by 2030. Federal "cash for clunkers" program results in all inefficient passenger and freight vehicles produced prior to 2010 being retired by 2030. Nationwide, VMT are reduced 2% by 2025 and 3.25% by 2030 relative to reference case. Biofuels grow by the same amount annually as under the Bottom-Up scenario (cellulosic by 30%, biodiesel by 10%, and advanced biofuels by 2% annually).

PRINCIPLE 2 DECARBONIZE END-USES	SCENARIO	SCENARIO ASSUMPTIONS
Industry	Current Measures	No modeled policies
	Bottom-Up	States adopt industrial efficiency programs, either mandatory or voluntary, that improve energy performance (e.g. ISO50001 standards). By 2030, Tier 1 states incentivize 75% of industrial facilities in state to adopt efficiency programs which result in 5% improvement in first year and 1% improvement thereafter. Tier 2 states also adopt incentives applicable to 50% of industrial facilities by 2030. Reflecting bipartisan support for industrial programs, Tier 3 states adopt incentives reaching 10% of industrial facilities by 2030. In Tier 1 and 2 states, electrified technologies make up 42% of new process heat sales, 25% of new curing equipment sales, 22% of new space heating sales, and 13% of new drying equipment sales by 2030. In Tier 3 states, electrified technologies make up 27% of new process heat sales, 10% of new curing equipment sales, 13% of new space heating sales, and 5% of new drying equipment sales by 2030. Tier 1 states reduce cement emissions 22% from 2018 levels by 2030 due to Buy Clean programs.
	All-In	Nationally, 100% of industrial facilities nationwide adopt industrial efficiency program by 2030. Nationally, electrified technologies make up 42% of new process heat sales, 25% of new curing equipment sales, 22% of new space heating sales, and 13% of new drying equipment sales by 2030. All states achieve cement emissions reductions of 20% from 2018 levels by 2030 due to federal Buy Clean policies.
HFCs	Current Measures	Federal EPA Section 608 Refrigerant Management Program remains in place. Current state-level SNAP rules reducing HFC emissions from refrigerants are enforced in CA, WA, and VT.
	Bottom-Up	SNAP rules reducing HFC emissions from refrigerants and aerosols are achieved in all Tier 1 states. SNAP rules reducing HFC emissions from refrigerants only are achieved in Tier 2 states. 50% of supermarkets nationwide achieve reductions in HFC emissions from cooling equipment, in-line with average leakage reduction rates historically achieved through EPA's GreenChill program.
	All-In	Federal enforcement of refrigerant management programs, SNAP rules, and Kigali Amendment provisions results in 40% reduction in HFC emissions by 2030 from 2013 levels.
PRINCIPLE 3 ENHANCE ECOSYSTEMS	**SCENARIO**	**SCENARIO ASSUMPTIONS**
Natural & Working Land Use and Agriculture Emissions	Current Measures	Land sink remains at current levels and does not degrade through 2030
	Bottom-Up	CA achieves -40 metric tons CO_2e by 2030. Other Tier 1 States achieve 60% of additional mitigation potential of top 11 Natural Climate Solutions at $10/ton, using Nature4Climate's US State Mapper. Tier 2 states achieve 30% of potential. Together this improves the land sink by 79 Mt CO_2e
	All-In	CA achieves -40 metric tons CO_2e by 2030. Other Tier 1 States achieve 60% of additional mitigation potential of top 11 Natural Climate Solutions at $10/ton, using Nature4Climate's US State Mapper. Tier 2 states achieve 30% of potential. Together this improves the land sink by 167 Mt CO_2e.

CROSS-CUTTING	SCENARIO	SCENARIO ASSUMPTIONS
Economy-Wide GHG Targets / Caps	Current Measures	California achieves its mandated 40% by 2030 reduction goal under SB 32.
	Bottom-Up	All tier 1 states with legislated economy-wide caps meet their goals in 2030 (or are on track to meet them if the target is post-2030). All tier 1 states with executive orders or goals meet 75% of their goals in 2030 (or are on track to meet 75% of the goal if the target is post-2030).
	All-In	Achievement of economy-wide caps in the Bottom-Up scenario is carried over into the All-In scenario, non-binding caps are also achieved in full.
Non-CO_2 (Other Methane and Nitrous Oxide)	Current Measures	NA
	Bottom-Up	100% of the non-CO_2 mitigation potential at $0/ton or less is achieved by all states for livestock, landfill, coal mining, nitric and adipic acid, and croplands.
	All-In	All states achieve 100% of the potential for non-CO_2 mitigation at $100/ton or less for livestock and $30/ton for landfill methane, coal mining, croplands, and nitric and adipic acid.

ACCELERATE TOWARD 100% CLEAN ELECTRICITY: SECTOR-SPECIFIC SUMMARY TABLES

The following sector subsections contain summary policy and modeling assumption tables that broadly outline central assumptions and the institutional sources of relevant information.

Note: All assumptions are additive from one scenario to the next (for example, any assumed policy achievement in the Bottom-Up scenario is assumed in the All-In scenario as well). For more information on which studies from listed sources were used, please see the sections above and the included citations.

Table 12 | Renewable Electricity Generation (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	Current state RPS demand through 2030; NREL Annual Technology Baseline (ATB) 2019 Mid Technology Cost Scenario.	NREL,[110] LBL,[111] EIA historic data.[112] Supplementary research on specific renewable energy targets and commitments.
Bottom-Up	Accelerated RPS demand through 2030 (60%, 40%, and 20% in Tier 1, 2 and 3 states, respectively); Additional renewable demand from city- and utility-level commitments; NREL ATB Low Technology Cost Scenario.	See references above. Additional assumptions developed through independent assessment and expert consultation.
All-In	Federal Clean Energy Standard; Further accelerated RPS demand in Tier 2 and 3 states; NREL ATB Low Technology Cost Scenario.	See references above. Additional assumptions developed through independent assessment and expert consultation.

Table 13 | Coal Generation (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCE
Current Measures	In 2020, announced retirements based on EIA reporting In 2025, units in deregulated markets that were uneconomic for 5 of last 6 years between 2012-2017 retire. In 2030, coal units in any market that had net operating losses for last 6 years retire.	EIA,[113] BNEF,[114] Moody's,[115] IEEFA.[116] Additional insight and expert consultations, including from Sierra Club
Bottom-Up	All coal units retire in Tier 1 states, except Pennsylvania by 2030. Units in deregulated markets that operated at loss 60% of years modeled retire by 2025 and at loss 50% of years modeled retire by 2030. Units in traditional markets that operated at loss for 75% of years modeled retire by 2025 and for 60% of years retire by 2030. PA, OH, TX, MI, MO, GA, NC, IN, KY, and WV experience no additional unannounced retirements through 2025, but by 2030, units in these states retire if they have been uneconomic for 90% of years modeled. For remaining units in service, capacity utilization decreases from 53% today to 47% by 2030.	See above references
All-In	Essentially all uncapped coal generation is retired	See above references

Table 14 | Nuclear Generation (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	12,731 MW of at-risk capacity does not close because of existing policy actions in NY, IL, CT, NJ, OH. 8,313 MW of other at-risk capacity retires. Georgia Vogtle Units come online in 2020-2021 with 2200 MW. Nuclear generates 749 TWh in 2030.	DOE and EIA[117] for plant sizes. Various sources including Union of Concerned Scientists for individual plants expected to close and plants scheduled to close that have been preserved.
Bottom-Up	In addition to current measures, several other states enact policies to preserve ~2,635 MW of the 8,313 MW of other at-risk nuclear capacity. Note 3,043 MW of the 8,313 MW cannot be feasibly saved, and we assume that of the remaining amount, half is saved. Nuclear generates 770 TWh in 2030.	See above references
All-In	Nuclear generation roughly equivalent to Bottom-Up scenario at 774 TWh in 2030.	Resources for the Future[118]

Table 15 | Gas Generation (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	No specific policy or assumption was modeled	N/A
Bottom-Up	Slower expansion of gas growth after 2020	Rocky Mountain Institute[119]
All-In	Assumed no new gas without CCUS and faster retirement of existing gas plants after 2020	See above reference

Table 16 | Carbon Capture, Utilization, and Storage (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	No significant CCUS deployment	
Bottom-Up	Moderate CCUS deployment in electric and industrial sectors, taking advantage of 45Q tax incentives.	Energy Futures Initiative[120]
All-In	CCUS scales rapidly with industrial CCUS removing 50 MMT CO_2e annually and electric sector CCUS removing 160 MMT CO_2e annually in 2030.	See above reference

Table 17 | Oil and Gas Methane (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	Federal NSPS achieved at 75% effectiveness due to policy uncertainty; Additional mitigation from state regulations on new and/or existing sources.	EDF,[121] EIA,[122] additional assumptions developed through independent assessment and expert consultation.
Bottom-Up	Federal NSPS achieved at 75% effectiveness in tier 1 states, whereas 100% of mitigation is achieved in tier 1 and 2 states; Additional mitigation from aspirational state regulations on new and existing sources.	See above references
All-In	Federal NSPS achieved at 100% effectiveness starting in model year 2022; Aspirational federal policy for new and existing sources reaching 60% mitigation by 2030 achieved.	See above references

Table 18 | Summary of Key Metrics – Modeling Assumptions (share of clean electricity in scenarios)

SCENARIO	2017	2020	2025	2030
Current Measures	36%	36%	38%	42%
Bottom-Up	36%	36%	48%	60%
All-In	36%	37%	56%	76%

▲ **Unit of analysis: Percent of total electricity generation by model year.**

Notes: Values represent the combined generation mix of renewables (hydro and non-hydro), nuclear, biomass, and gas with CCUS, by scenario.

Table 19 | Projected U.S. Nuclear Generation in the Scenarios

SCENARIO	2017	2020	2025	2030
Current Measures	805	792	749	749
Bottom-Up	805	792	770	770
All-In	805	792	784	774

▲ **Unit of analysis: TWh**

Table 20 | Projected Coal Generation Generation in the Scenarios

SCENARIO	2017	2020	2025	2030
Current Measures	1,205	1,149	878	687
Bottom-Up	1,205	1,149	614	317
All-In	1,205	1,149	474	~0

▲ Unit of analysis: TWh

Table 21 | Mitigation of Oil and Gas System Methane IN THE Scenarios – Modeling Inputs

SCENARIO	2017	2020	2025	2030
Current Measures	6%	15%	20%	23%
Bottom-Up	6%	20%	30%	34%
All-In	6%	20%	49%	60%

▲ Unit of analysis: % of national reference case oil and gas methane emissions reduced.

DECARBONIZE END-USES

Table 22 | Building Efficiency (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	Electricity and gas savings from current binding state EERS policies. Minimum annual EERS savings of 2% and 1.5% in Tier 1 and 2 states, respectively. Additional savings achieved.	ACEEE,[123 124] EIA,[125] PNNL,[126] NEEP REED database,[127] additional assumptions developed through independent assessment and expert consultation.
Bottom-Up	Electricity and gas savings from non-binding state EERS policies. Minimum annual EERS savings of 2% and 1.5% in Tier 1 and 2 states, respectively. Savings from state level building code adoption. Additional energy savings from current city targets and adoption of stretch codes in leading cities.	See above references, additional assumptions developed through independent assessment and expert consultation.
All-In	Additional residential sector savings through federal Weatherization Assistance Program.	See above references, ORNL,[128 129 130 131] additional assumptions developed through independent assessment and expert consultation.

Table 23 | Building Electrification (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	No actions modeled	
Bottom-Up	California, Florida, Georgia, South Carolina, North Carolina, Alabama, Mississippi, Louisiana, Arkansas, Tennessee, and Virginia achieve 2030 electric appliance sales penetration rates of 86% of residential space heating, 59% of residential water heating, 71% of commercial space heating, 40% of commercial water heating, and 99.5% of commercial cooking. Remaining Tier 1 and 2 states achieve electric appliance sales penetration rates of 60% of residential space heating, 44% of residential water heating, 39% of commercial space heating, 18% of commercial water heating, and 42% of commercial cooking by 2030. Remaining Tier 3 states achieve electric appliance sales percentages of 49% of residential space heating, 38% of residential water heating, 24% of commercial space heating, 7% of commercial water heating, and 33% of commercial cooking by 2030.	NREL,[132] EPRI[133] NREL[134], additional assumptions developed through independent assessment and expert consultation.
All-In	Nationwide, all states achieve high electrification of appliances equivalent to Tier 1 and 2 states above, with the exception of the 11 states mentioned above, who continue to achieve the higher sales penetration rates.	See above references NREL[135], additional assumptions developed through independent assessment and expert consultation.

Table 24 | Light-Duty Vehicle Standards (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	All states and automakers improve GHG performance of new cars and trucks consistent with the compromise offered by California of 3.7% per year through 2025. No standards post 2025.	California Air Resources Board[136]
Bottom-Up	Tier 1 and 2 states finalize ambitious standards for vehicles that improve conventional vehicle performance 40 gpm between 2025-2030 while also incentivizing rapid shift to EVs (see below).	EDF,[137] ICCT[138]
All-In	Federal government restores original ambition of Obama era standards. National standards improve conventional vehicle performance 40 gpm between 2025-2030 while incentivizing rapid shift to EVs.	See above references

Table 25 | Zero Emissions Vehicles (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	ZEV state targets, state fleet procurement targets.	EIA[139 140], supplementary research on specific state and city targets.
Bottom-Up	For Tier 1 & 2 states, 67% of LDV sales are electric (38% BEV and 29% PHEV) while 20% of medium-duty, 15% of heavy-duty, and 60% of bus sales are electric by 2030. For Tier 3 states, 63% of LDV sales (30% BEV and 33% PHEV), 10% of MDV, 3% of HDV, & 20% of bus sales are electric by 2030.	NREL[141], LBNL[142], NACFE[143], CARB[144]; additional assumptions developed through independent assessment and expert consultation.
All-In	Nationwide, 67% of LDV sales are electric (38% BEV and 29% PHEV) while 20% of medium-duty, 15% of heavy-duty, and 100% of bus sales are electric by 2030.	See above references; additional assumptions developed through independent assessment and expert consultation.

Table 26 | Vehicle Miles Traveled (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	Reductions from current on-the-books state-level VMT targets.	ACEEE,[145] FHWA,[146], NREL,[147] supplementary research on state and city targets.
Bottom-Up	Tier 1 states reduce VMT 2% by 2030 (unless state target is higher). Additional reductions from currently pledged city-level targets.	See above references; additional assumptions developed through independent assessment and expert consultation.
All-In	All states reduce VMT 2% by 2025 and 3.25% by 2030 (unless state target is higher).	See above references; additional assumptions developed through independent assessment and expert consultation.

Table 27 | Industrial Efficiency and Electrification (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	No actions modeled.	
Bottom-Up	All states adopt industrial performance standards that improve efficiency of existing facilities. By 2030, 75% of facilities in Tier 1 states adopt efficiency standards that improve efficiency 5% in first year and 1% annually thereafter. 50% of facilities in Tier 2 states and 20% of facilities in Tier 3 states adopt equivalent standards. States encourage rapid electrification with Tier 1 and 2 states electrifying 25% of new curing equipment, 13% of new drying equipment, 42% of other new process heat, and 22% of new space heating. Tier 3 states electrify 10% of new curing equipment, 5% of new drying equipment, 27% of other new process heat, and 13% of new space heating. Tier 1 states adopt Buy Clean standards reducing cement emissions 22% by 2030.	LBNL[148], NREL[149] , Energy Futures Initiative[150]
All-In	All states adopt efficiency performance standards applicable to 100% of industrial facilities by 2030. All states achieve high electrification of industrial equipment equivalent to Tier 1 and 2 states above. All states adopt Buy Clean standards reducing cement emissions 22% by 2030.	See above references; additional assumptions developed through independent assessment and expert consultation.

Table 28 | HFCs (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	Mitigation from EPA Sect. 608 RMP and CA RMP. Additional mitigation from currently legislated state level SNAP rules.	EPA,[151] CARB,[152] WRI,[153] additional assumptions developed through independent assessment and expert consultation.
Bottom-Up	SNAP rules covering aerosols and refrigerants and refrigerants only adopted in Tier 1 and 2 states, respectively. Tier 1 and 2 states adopt more stringent RMP. 50% of supermarkets nationwide reduce leak-age in-line with average reduction rates historically achieved through EPA's GreenChill program.	See above references; additional assumptions developed through independent assessment and expert consultation.
All-In	Significant reductions achieved in all states through federal enforcement of refrigerant management programs, SNAP rules, and Kigali Amendment.	See above references; additional assumptions developed through independent assessment and expert consultation.

Table 29 | Summary of Key Metrics – Modeling Inputs and Results (total annual light-duty zev sales – modeling inputs)

SCENARIO	2017	2020	2025	2030
Current Measures	152,000	582,000	1,334,000	1,754,000
Bottom-Up	152,000	587,000	5,170,000	9,982,000
All-In	152,000	587,000	5,353,000	10,198,000

▲ Unit of analysis: Total ZEV sales (BEV + PHEV) for all light-duty vehicles (including light-duty cars and trucks).

Table 30 | Total Annual Electrified Freight Ton-Kilometers – Modeling Results

SCENARIO	2017	2020	2025	2030
Current Measures	0	277	921	2,254
Bottom-Up	0	10,935	32,716	66,940
All-In	0	19,062	39,457	78,203

▲ Unit of analysis: Total electrified ton-kilometers for on-road freight movement (including medium- and heavy-duty trucks).

Table 31 | Change in Vehicle Liquid Fuel Demand – Modeling Results

SCENARIO	2017	2020	2025	2030
Current Measures	-	-2%	-3%	-5%
Bottom-Up	-	-3%	-6%	-15%
All-In	-	-4%	-10%	-29%

▲ Unit of analysis: % Change in liquid fuel demand relative to reference case – all vehicle types.

Table 32 | New Vehicle Emissions Standards – Modeling Inputs

SCENARIO	VEHICLE TYPE	2017	2020	2025	2030
Current Measures	Cars	280	250	212	212
	Light Trucks	386	355	287	287
Bottom-Up	Cars	280	250	212	187
	Light Trucks	386	355	287	261
All-In	Cars	280	250	203	162
	Light Trucks	386	355	275	235

▲ Unit of analysis: National Average New Conventional Vehicle CO_2 Emission Performance (grams of CO_2 per mile).

Table 33 | Mitigation of HFC Emissions in the Scenarios – Modeling Inputs

SCENARIO	2017	2020	2025	2030
Current Measures	-	7%	8%	9%
Bottom-Up	-	8%	24%	29%
All-In	-	8%	32%	49%

▲ Unit of analysis: % of national reference case HFC emissions reduced.

ENHANCE ECOSYSTEMS

Table 34 | Land Use (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	Land sink remains flat. No state or city measures are included in our estimates of Current Measures.	EPA[154]
Bottom-Up	CA achieves -40 Mt CO_2e by 2030. Other Tier 1 States achieve 60% of additional migitation potential of top 11 Natural Climate Solutions at $10/ton. Tier 2 states achieve 30% of potential.	Assumptions developed with Nature 4 Climate's US State mapper and expert judgement[155]
All-In	CA achieves -40 Mt CO_2e by 2030. All other states achieve 60% of additional mitigation potential of top 11 Natural Climate Solutions at $10/ton by 2030 (full potential achieved by 2050 with longer time period resulting from delays in reaching land owners and institutions that are hard to reach)	Same as above

Table 35 | Summary of Key Metrics – Modeling Inputs and Results (net land use emissions in the scenarios – modeling inputs)

SCENARIO	2017	2020	2025	2030
Current Measures	-714	-714	-714	-714
Bottom-Up	-714	-714	-754	-793
All-In	-714	-714	-797	-881

▲ Unit of analysis: Mt CO_2e. Note that these are point estimates and do not reflect the estimated range of uncertainty.

CROSS-CUTTING

Table 36 | Carbon Pricing and GHG Caps (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	Achievement of current RGGI caps in Northeast states and CA AB32 / SB32 40% by 2030 goal.	C2ES,[156] CARB,[157] additional assumptions developed through independent assessment and expert consultation.
Bottom-Up	States with legislated targets fully achieve 2030 GHG caps (or are on track to meet post-2030 caps); States with non-legislated targets achieve 75% of 2030 GHG caps (or are on track to meet 75% of post-2030 caps).	Data on GHG caps acquired through independent research and sourcing. Additional assumptions developed through independent assessment.
All-In	All states with targets (legislated or otherwise) fully achieve their 2030 GHG caps (or are on track to meet post-2030 caps).	See above references.

Table 37 | Other Methane and Nitrous Oxide (assumptions and sources)

SCENARIO	POLICY & MODELING ASSUMPTIONS	SOURCES
Current Measures	Baseline emissions	EPA[158]
Bottom-Up	Potential for mitigation achieved at a cost of $0/ton or less for methane from livestock, landfills, coal mining, and crops, and nitrous oxide from crops and nitric and adipic acid production	See above references.
All-In	Potential for Non-CO_2 mitigation achieved at a cost of $100/ton or less for methane from livestock and $30/ton or less for methane from landfills, coal mining and crops, and nitrous oxide from crops and nitric and adipic acid production	See above references.

Table 38 | Other Methane and Nitrous Oxide Emissions in the Scenarios in 2030 – Modeling Inputs

SECTOR	CURRENT MEASURES	BOTTOM-UP	ALL-IN
Coal mining methane	44.9	40.4	16.3
Croplands Nitrous Oxide	341.0	334.7	334.7
Livestock Methane	246.0	245.5	175.8
Livestock Nitrous Oxide	18.9	18.9	17.3
Landfill Methane	124.0	122.4	115.1
Nitric and Adipic Acid	28.6	28.6	10.9

▲ Unit of analysis: Mt CO_2e in 2030

Notes: The source is the EPA's Global Non-CO_2 Greenhouse Gas Emission Projections & Mitigation: 2015-2050.

Table 39 Summary of Key Metrics – Modeling Inputs and Results (reductions from GHG caps in the scenarios – modeling inputs)

SCENARIO	2017	2020	2025	2030
Current Measures	1%	1%	3%	4%
Bottom-Up		3%	6%	10%
All-In		4%	7%	11%

▲ Unit of analysis: % of national reference case economy-wide emissions reduced.

Appendix B:
Data and Methodology: Non-Federal Entities with GHG Targets & Networks Supporting the Paris Agreement

This section describes the methodology and provides the numeric results underlying Table 1 and Table 2 of the updated footprint analysis, which depict the population, GDP or market cap, and emissions of:

1. Non-federal entities with GHG targets, and
2. Networks of non-federal entities supporting the Paris Agreement.

Unless otherwise noted, these figures contain no missing values. These data were collected by CDP (formerly Carbon Disclosure Project), and the methodology was developed jointly by CDP, RMI, and WRI for the America's Pledge Phase 1 Report and has been subsequently updated for the current report.

NON-FEDERAL ENTITIES WITH GHG TARGETS

This portion of the analysis documents the number of non-federal entities that have enacted GHG targets. These targets, while numerous, vary in terms of level of ambition and therefore magnitude of expected emission reductions. Many are voluntary and could be dropped with little consequence, and others adopted under previous political administrations may already be inactive.

Table 40 | **Entities Committing to GHG Emission Reduction Targets**

	NUMBER OF ACTORS[1]	POP. AND SHARE OF NATIONAL POP[2]		GDP (MILLION $) AND SHARE OF NATIONAL GDP[3]		MARKET CAP (MILLION $)[4]	REPORTED EMISSIONS (MT CO_2 2017-2019) AND SHARE OF NATIONAL EMISSIONS		EMISSIONS WITH ESTIMATES (MT CO_2E 2016-2019 AND SHARE OF NATIONAL EMISSIONS	
States	25	202,531,403	62%	$13,713,946	65%	N/A	1,191,625,754	18%	2,943,812,156	45%
Counties	16	15,791,789	5%	$1,194,252	6%	N/A	66,966,591	1%	205,859,961	3%
Cities	176	60,704,429	19%	$4,330,811	20%	N/A	505,038,263	8%	682,951,193	11%
Combined States, Counties, & Cities	1,932	N/A	N/A	N/A	N/A	$32,866,096	1,129,000,258	17%	N/A	N/A
Businesses & Investors (US-headquartered only)	1,005	N/A	N/A	N/A	N/A	$19,514,717	979,015,410	15%	N/A	N/A
Universities[6]	593	5,365,258	2%	N/A	N/A		25,406,739	0.4%	N/A	N/A

[1] As of September 1, 2019

[2] U.S. Census est. July 2018. Enrollment for universities 2017-2019.

[3] Million U.S. dollars. BEA estimate 2017-2019

[4] As of September 6, 2019

[5] Sharre of national emissions based on EPA Inventory 2019

[6] 2017 – 2019 Second Nature

Number of Entities: For states*, the count of entities that have publicly announced or recorded a GHG emissions target is based on data from CDP, Under2MOU, C2ES, or public announcement by the state or territorial government.[159] [160] [161] [162] For counties and cities, the counts of entities that have recorded or announced a GHG emissions target are based on data from CDP, Under2MOU, ICLEI carbon*n*, ACEEE, or public announcement by the local government.[163] [164] [165] [166] [167] For businesses and investors, the counts of entities that have either reported emissions in the United States and a GHG emissions reduction target or that are headquartered in the United States and reported a GHG emissions target are through CDP, Science-Based Targets Initiative, or public announcement by the company.[168] [169] [170] For universities, the count of entities that have registered a climate or carbon commitment is through Second Nature.[171] "Combined States, Counties, & Cities" aggregates the number of states, counties, and cities that have adopted a GHG target.

Population: Sum of the most recent U.S. Census estimates available for entities with a GHG target in each subnational actor category: states, counties, and cities. The 2018 Population Estimates (as of July 1, 2018) were used; elsewhere, the 2017 American Community Survey 5-year Estimates were used.[172] [173] Percentage of national population is based on U.S. Census estimate for the resident population of U.S. states (including the District of Columbia and Puerto Rico) as of July 1, 2018. "Combined States, Counties, & Cities" aggregates the population of states, counties, and cities that have adopted a GHG target, adjusting for double counting by excluding cities and counties located in states that also have targets, as well as cities located in counties that also have targets. For universities, population is the sum of enrollment figures provided to Second Nature in 2017-2019.[174]

GDP: For states, Bureau of Economic Analysis (BEA) estimates of current-dollar gross domestic product (GDP) by state for first quarter 2019 and a separately sourced GDP figure for Puerto Rico were summed.[175] [176] For counties and cities, BEA estimates of the real gross domestic product of U.S. metropolitan areas were allocated based on the proportion of the total U.S. Census estimated metropolitan area population that the county or city represented.[177] Where metropolitan area gross domestic product or population estimates were not available, a percentage of the BEA state GDP estimate was allocated based on the proportion of the total estimated state population that the county or city represents.

The percentages of national GDP were calculated based on the sum of the BEA estimate of current-dollar gross national GDP for first quarter 2019 and the most recent figure for Puerto Rico. "Combined States, Counties, & Cities" aggregates the estimated GDP of states, counties, and cities that have adopted a GHG target, adjusting for double counting by excluding cities and counties located in states that also have targets, as well as cities located in counties that also have targets.

Market Capitalization: Aggregate figures represent the sum of market capitalization figures in USD available through the Bloomberg Terminal on September 6, 2019 for all public companies reporting both emissions in the U.S. and an emissions reduction target in their 2017-2019 CDP climate change disclosures.[178] Of the 1,932 companies that report emissions in the U.S., market cap figures were available for 1,163 companies, with most of the missing values from private or subsidiary companies. Of the 1,005 US-headquartered companies, market cap figures were available for 445 companies. These figures are not localized and represent the total market capitalization of companies' global operations.

Emissions: For each actor type or group of actors, two separate calculations were made: one based only on emissions figures directly reported by the actor, and the other based on both reported emissions and estimated emissions figures.

For states, reported emissions are sourced from emissions inventories disclosed through the 2019 CDP states and regions questionnaire.[179] Where reported emissions were not available, gross emissions were estimated using the EPA's State Inventory Tool using default settings and pre-loaded data for the most recent year (2016).[180] For Puerto Rico, the U.S. Energy Information Administration (EIA) figure for carbon dioxide emissions from total fossil fuels in 2016 (5,240 million metric tons) was used.[181] Please note that in previous versions of the America's Pledge footprint analysis, state-level emissions estimates based on the State Inventory Tool were included as reported emissions. In this year's footprint, they have been reclassified as estimated values.

For cities and counties, reported emissions data are sourced from emissions inventories disclosed through the 2018 CDP cities questionnaire, the CDP and ICLEI unified reporting system in 2019, or by public announcement of the local government.[182] Where reported data were not available, U.S. Energy Department State and Local Energy Data (SLED) estimates were used.[183] For businesses and investors, reported emissions include scope 1 emissions figures for the U.S. only disclosed

* "States"includes Puerto Rico.

through the 2017-2019 CDP climate change questionnaires.[184] Of the 1,932 companies that report emissions in the U.S., scope 1 emissions figures were available for 1,326 companies. Of the 1,005 US-headquartered companies, scope 1 emissions figures were available for 595 companies. For universities, emissions data were reported through Second Nature.[185]

The percentages of national GHG emissions were calculated based on EPA's most recent figure for gross emissions of the United States (including the District of Columbia and all territories) in 2017.[186] "Combined States, Counties, & Cities" aggregates the emissions of states, counties and cities that have adopted a GHG target, adjusting for double counting by excluding cities and counties in states that also have targets, as well as cities located in counties that also have targets.

COALITIONS SUPPORTING THE PARIS AGREEMENT

This portion of the analysis documents the scope of coalitions formed explicitly to support the objectives of the Paris Agreement. While several coalitions undertake activities in line with the targets and objectives of the Paris Agreement, three coalitions have formed explicitly to demonstrate non-federal commitment to the Agreement. Two of these coalitions—We Are Still In (WASI) and the United States Climate Alliance—were formed immediately following the announcement of President Trump's intention to withdraw from the Agreement. The third—Climate Mayors—was formed in 2014.

Number of Entities: Counts include the sum of the number of actors in each coalition and breakdowns of total number of actors by type that have signed onto at least one coalition as of September 1, 2019.[187 188 189] "Combined States, Counties, & Cities" aggregates the number of cities, counties and states that are part of at least one coalition. For this row, estimates of population, GDP, and emissions are corrected for overlap, however the "number of actors" count is an unadjusted sum for all state, city, and county entities (for example, both Duluth—a WASI city—and Minnesota—a U.S. Climate Alliance state) are both included in the total).

Population: Sum of the most recent U.S. Census estimates available for entities in each coalition and for each subnational actor category: states, counties, and cities. The 2018 Population Estimates (as of July 1, 2018) were used; elsewhere, the 2017 American Community Survey 5-year Estimates were used.[190 191] The percentages of national population are based on U.S. Census estimate for the resident population of U.S. states (including the District of Columbia and Puerto Rico) as of July 1, 2018.[192]

The following adjustments were made to avoid double counting:

- "WASI" aggregates the population of states, counties, and cities that are part of WASI, adjusting for double counting by excluding cities and counties in states in WASI, and cities in counties in WASI.
- "Combined States, Counties, & Cities" aggregates the population of states, counties, and cities that are part of at least one coalition, adjusting for double counting by excluding cities and counties in states in either WASI or the U.S. Climate Alliance, and cities in counties that are also in WASI.

GDP: For states, Bureau of Economic Analysis (BEA) estimates of current-dollar gross domestic product (GDP) by state for first quarter 2019 and a separately sourced GDP figure for Puerto Rico were summed.[193 194] For counties and cities, BEA estimates of the real gross domestic product of U.S. metropolitan areas were allocated based on the proportion of the total U.S. Census estimated metropolitan area population that the county or city represented.[195] Where metropolitan area gross domestic product or population estimates were not available, a percentage of the BEA state GDP estimate was allocated based on the proportion of the total estimated state population that the county or city represents.

Table 41 | Coalitions Expressing Support for the Paris Agreement

	Number of Actors[1]	Population and Share of National Pop.[2]		GDP (Million $) and Share of National GDP[3]		Reported Emissions (MT CO_2 2017-2019) and Share of National Emissions[4]		Emissions with Estimates (MT CO_2E 2016–2019) and Share of National Emissions[4]	
WASI	3,751	144,817,117	44%	$10,387,349	49%	1,429,848,341	22%	2,050,997,137	32%
U.S. Climate Alliance/ States	25	182,614,239	56%	$12,760,795	60%	1,191,625,754	18%	2,768,724,374	43%
Climate Mayors	426	70,578,164	22%	$5,008,443	24%	454,058,716	7%	800,948,587	12%
Cities	487	74,013,090	23%	$5,240,109	25%	473,896,268	7%	851,951,846	13%
Counties	37	39,380,215	12%	$2,948,409	14%	39,220,125	0.6%	609,468,826	9%
Combined States, Counties, & Cities	549	211,236,028	65%	$14,469,234	68%	1,432,717,360	22%	3,285,746,329	51%
Artists	23								
Businesses	1,870								
Cultural Institutions	64								
Faith Organizations	917								
Health Care Organizations	38								
Higher Education Institutions	400								
Investors	138								
Tribes	10								

[1] As of September 1, 2019

[2] U.S. Census estimate July 2018

[3] BEA est. 2017-2019

[4] EPA GHG Inventory 2019

The percentages of national GDP are based on the sum of the BEA estimate of current-dollar gross national GDP for first quarter 2019 and the most recent figure for Puerto Rico.[196]

The following adjustments were made to avoid double counting:

- "WASI" aggregates the GDP of states, counties, and cities that are part of WASI, adjusting for double counting by excluding cities and counties in states in WASI, and cities in counties in WASI.
- "Combined States, Counties, & Cities" aggregates the GDP of states, counties, and cities that are part of at least one coalition, adjusting for double counting by excluding cities and counties in states in either WASI or the U.S. Climate Alliance, and cities in counties in WASI.

Emissions: For each coalition, subnational actor type, or combination of actors, two separate calculations were made: one based only on emissions figures directly reported by the actor, and the other based on both reported emissions and estimated emissions figures.

For states, reported emissions are sourced from emissions inventories disclosed through the 2019 CDP states and regions questionnaire.[197] Where reported emissions were not available, gross emissions were estimated using the EPA's State Inventory Tool using default settings and pre-loaded data for the most recent year (2016).[198] For Puerto Rico, the U.S. Energy Information Administration (EIA) figure for carbon dioxide emissions from total fossil fuels in 2016 (5,240 million metric tons) was used.[199] Please note that in previous versions of the America's Pledge footprint analysis, state-level emissions estimates based on the State Inventory Tool were included as reported emissions. In this year's footprint, they have been reclassified as estimated values.

For cities and counties, reported emissions data are sourced from emissions inventories disclosed through the 2018 CDP cities questionnaire, the CDP and ICLEI unified reporting system in 2019, or by public announcement of the local government.[200] [201] Where reported data were not available, U.S. Energy Department State and Local Energy Data estimates were used.[202]

The percentages of national GHG emissions were calculated based on EPA's most recent figure for gross emissions of the United States (including the District of Columbia and all territories) in 2017.[203]

The following adjustments were made to avoid double counting:

- "WASI" aggregates the emissions of states, counties, and cities that are part of WASI, adjusting for double counting by excluding cities and counties in states in WASI, and cities in counties in WASI.
- "Combined States, Counties, & Cities" aggregates the emissions of states, counties, and cities that are part of at least one coalition, adjusting for double counting by excluding cities and counties in states in either WASI or the U.S. Climate Alliance, and cities in counties in WASI.

Endnotes

1 New Climate Institute, World Resources Institute, CDP, and The Climate Group. “Non-State and Subnational Action Guidance.” Initiative for Climate Action Transparency, July 26, 2017. http://www.climateactiontransparency.org/wp-content/uploads/2017/07/ICAT-Non-State-and-Subnational-Action-Guidance-26-JUL-2017.pdf

2 Kovac, Alex, and Wee Kean Fong. “Compact of Mayors Emissions Scenario Model.” Technical Note. World Resources Institute, December 2015. https://www.wri.org/sites/default/files/Compact_of_Mayors_Emissions_Scenario_Model.pdf

3 David Rich, Pankaj Bhatia, Jared Finnegan, Kelly Levin, Apurba Mitra. “Policy and Action Standard, an accounting and reporting standard for estimating the greenhouse gas effects of policies and actions.” Greenhouse Gas Protocol. https://ghgprotocol.org/sites/default/files/standards/Policy%20and%20Action%20Standard.pdf

4 Energy Information Administration. 2019. Annual Energy Outlook 2019. https://www.eia.gov/outlooks/aeo/

5 Bloomberg New Energy Finance. 2019. New Energy Outlook. https://about.bnef.com/new-energy-outlook/

6 Moody’s. 2019. "U.S. coal’s shrinking share of power generation may fall to 11% by 2030." July 10, 2019. https://www.spglobal.com/marketintelligence/en/news-insights/trending/MShmo4U4USAkqoyf7mEhDw2

7 Institute for Energy Economics and Financial Analysis. 2019. Coal Outlook 2019: Domestic Market Decline Continues. http://ieefa.org/wp-content/uploads/2019/03/Coal-Outlook-2019_March-2019.pdf

8 Nelson, W., and S. Liu. “Half of U.S. Coal Fleet on Shaky Economic Footing: Coal Plant Operating Margins Nationwide.” Bloomberg New Energy Finance, 2018.

9 U.S. Energy Information Administration. “U.S. Nuclear Generation and Generating Capacity.” Accessed Aug 2019. https://www.eia.gov/nuclear/generation/

10 U.S. Department of Energy. “Vogtle.” https://www.energy.gov/lpo/vogtle

11 U.S. Energy Information Administration (EIA). Annual Electric Power Industry Report, Form EIA-861 detailed data files. https://www.eia.gov/electricity/data/eia861/

12 Lawrence Berkeley National Lab (LBL). Renewables Portfolio Standards Resources. https://emp.lbl.gov/projects/renewables-portfolio

13 Wiser, R., G. Barbose, J. Heeter, T. Mai, L. Bird, M. Bolinger, A. Carpenter, G. Heath, D. Keyser, J. Macknick, A. Mills, and D. Millstein. 2016. A Retrospective Analysis of the Benefits and Impacts of U.S. Renewable Portfolio Standards. Lawrence Berkeley National Laboratory and National Renewable Energy Laboratory. NREL/TP-6A20-65005. http://www.nrel.gov/docs/fy16osti/65005.pdf

14 U.S. Department of Energy (DOE). State & Local Energy Data. https://www.eere.energy.gov/sled/#/

15 U.S. Energy Information Administration (EIA). Annual Electric Power Industry Report, Form EIA-861 detailed data files. https://www.eia.gov/electricity/data/eia861/

16 Sierra Club. 100% Commitments in Cities, Counties, & States. https://www.sierraclub.org/ready-for-100/commitments

17 CDP. 2018 - Cities Renewable Energy Targets. https://data.cdp.net/Renewable-Energy/2018-Cities-Renewable-Energy-Targets/eai5-mrwy

18 U.S. Department of Energy (DOE). Database of State Incentives for Renewables & Efficiency. https://www.dsireusa.org/

19 Smart Electric Power Alliance (SEPA). Utility Carbon Reduction Tracker. https://sepapower.org/utility-carbon-reduction-tracker/

20 Bloomberg New Energy Finance (BNEF). U.S. Plant Stack dataset.

21 U.S. Environmental Protection Agency (EPA). Emissions & Generation Resource Integrated Database (eGRID). https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

22 U.S. Environmental Protection Agency, “Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources,” Federal Register, June 3, 2016, Vol. 81, No. 107, https://www.gpo.gov/fdsys/pkg/FR-2016-06-03/pdf/2016-11971.pdf

23 U.S. Environmental Protection Agency. “Review of the 2016 Oil and Gas New Source Performance Standards for New, Reconstructed, and Modified Sources.” Federal Register / Vol. 82, No. 63, April 4, 2017. https://www.gpo.gov/fdsys/pkg/FR-2017-04-04/pdf/2017-06658.pdf

24 Regulations.gov, “Waste Prevention, Production Subject to Royalties, and Resource Conservation,” https://www.regulations.gov/document?D=BLM-2016-0001-9126

25 U.S. Department of the Interior, Bureau of Land Management, “BLM offers revision to methane waste prevention rule,” https://www.blm.gov/press-release/blm-offers-revision-methane-waste-prevention-rule

26 U.S. Environmental Protection Agency, “Natural Gas and Petroleum Systems in the GHG Inventory: Additional Information on the 1990-2016 GHG Inventory (published April 2018),” https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2016-ghg

27 This assumption that overlap is already accounted for is based on our conversations with an EPA representative working closely with the relevant programs.

28 U.S. Energy Information Administration (EIA). Annual Electric Power Industry Report, Form EIA-861 detailed data files. https://www.eia.gov/electricity/data/eia861/

29 U.S. Energy Information Administration (EIA). Natural Gas Consumption by End Use. https://www.eia.gov/dnav/ng/ng_cons_sum_a_EPG0_vgt_mmcf_m.htm

30 ACEEE’s State Energy Efficiency Scorecard ranks states on their efficiency policies and programs, assessing performance and also documenting best practices and recognizing leadership. Berg, Weston, Seth Nowak, Meegan Kelly, Shruti Vaidyanathan, Mary Shoemaker, Anna Chittum, Marianne DiMascio, and Heather DeLucia. “The 2017 State Energy Efficiency Scorecard.” American Council for an Energy-Efficient Economy, September 2017. http://aceee.org/sites/default/files/publications/researchreports/u1710.pdf

31 For more details, see: U.S. Environmental Protection Agency. 2014. “Background and Draft Methodology for Estimating Energy Impacts of EE/RE Policies.” Accessible at: Synapse. 2012. “State Energy Efficiency in the AEO Electricity Forecasts.” Accessible at http://www.synapse-energy.com/project/state-energy-efficiency-embedded-annual-energy-outlookforecasts. This methodology is also consistent with the examples EPA provided to support Clean Power Plan compliance in its technical support document entitled “Incorporating RE and Demand-Side EE Impacts into State Plan Demonstrations.” Accessible at: http://epa.gov/airquality/cpp/tsd-cppincorporating-re-ee.pdf

32 American Council for an Energy-Efficient Economy (ACEEE). State and Local Policy Database. https://database.aceee.org/

33 U.S. Department of Energy (DOE). State & Local Energy Data. https://www.eere.energy.gov/sled/#/

34 Personal conversation, David Ribeiro, Weston Berg, ACEEE, June 18, 2018.

35 American Council for an Energy-Efficient Economy, https://database.aceee.org.

36 U.S. Department of Transportation Federal Highway Administration, “Highway Statistics Series Publications,” https://www.fhwa.dot.gov/policyinformation/statistics.cfm

37 American Council for an Energy-Efficient Economy (ACEEE). https://database.aceee.org/

38 U. S. Department of Energy, Energy Efficiency & Renewable Energy, “State & Local Energy Data,” https://apps1.eere.energy.gov/sled/#

39 California Air Resources Board. 2019. Terms for Light-Duty Greenhouse Gas Emissions Standards. https://ww2.arb.ca.gov/sites/default/files/2019-07/Auto%20Terms%20Signed.pdf

40 The California Low-Emission Vehicle Regulations. “§ 1962.2 Zero-Emission Vehicle Standards for 2018 and Subsequent Model Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles.” Accessed August 16, 2018. https://www.arb.ca.gov/msprog/zevprog/zevregs/1962.2_Clean.pdf

41 U.S. Energy Information Administration (EIA). Annual Energy Outlook 2019. https://www.eia.gov/outlooks/aeo/tables_ref.php

42 U.S. Federal Highway Administration (FWHA). Highway Statistics 2017. https://www.fhwa.dot.gov/policyinformation/statistics/2017/mv1.cfm

43 U.S. Energy Information Administration (EIA). "Analysis of the Effect of Zero-Emission Vehicle Policies: State-Level Incentives and the California Zero-Emission Vehicle Regulations." https://www.eia.gov/analysis/studies/transportation/zeroemissions/pdf/zero_emissions.pdf

44 American Council for an Energy-Efficient Economy (ACEEE) https://database.aceee.org

45 The Court of Appeals remanded Rule 20, stating that the EPA could not use the SNAP program to require businesses to replace HFCs with alternatives after already requiring them to replace ozone-depleting substances with HFCs. (*Mexichem Fluor v. EPA,* https://www.cadc.uscourts.gov/internet/opinions.nsf/3EDC3D4817D618CF8525817600508EF4/$file/15-1328-1687707.pdf)

46 The EPA’s Updated Refrigerant Management Requirements: What Supermarkets and Property and Facility Managers Need to Know. https://www.epa.gov/sites/production/files/2016-09/documents/608_fact_sheet_supermarkets_property_managers_0.pdf

47 U.S. Environmental Protection Agency. “The EPA’s Updated Refrigerant Management Requirements: What Supermarkets and Property and Facility Managers Need to Know,” September 2016. https://www.epa.gov/sites/production/files/2016-09/documents/608_fact_sheet_supermarkets_property_managers_0.pdf

48 California Environmental Protection Agency, Air Resources Board. “Table B2. Reductions (MMT CO_2E) each calendar year, shown by equipment production year for all emissions sectors covered by proposed regulation,” Appendix B: Emission Estimates, https://www.arb.ca.gov/regact/2018/casnap/isorappb.pdf

49 Tom Land and U.S. Environmental Protection Agency (EPA). “GreenChill Annual Achievements.” presented at the Energy & Store Development Conference, September 2017. https://www.epa.gov/sites/production/files/2017-09/documents/gc_recognition.presentation_2017_ceremony.pdf

50 Ibid.

51 Tom Land and U.S. Environmental Protection Agency (EPA). “GreenChill Annual Achievements.” presented at the Energy & Store Development Conference, September 2017. https://www.epa.gov/sites/production/files/2017-09/documents/gc_recognition.presentation_2017_ceremony.pdf

52 EPA. “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017.” https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017

53 Tian, Xiaohui, Brent Sohngen, Justin Scott Baker, Sara Ohrel. 2018. "Will U.S. Forests Continue to Be a Carbon Sink." Land Economics: 94 (1). https://www.researchgate.net/publication/322669663_Will_US_Forests_Continue_to_Be_a_Carbon_Sink;

U.S. Department of Agriculture. 2016. USDA Integrated Projections for Agriculture and Forest Sector Land Use, Land-Use Change, and GHG Emissions and Removals: 2015-2060. https://www.usda.gov/oce/climate_change/mitigation_technologies/Projections2015documentation01192016.docx

54 U.S. Department of State. 2016. Second Biennial Report of the United States of America. https://unfccc.int/files/national_reports/biennial_reports_and_iar/submitted_biennial_reports/application/pdf/2016_second_biennial_report_of_the_united_states_.pdf

55 Climate Works Foundation. 2019. "Reducing Climate Policy Risk: Improving Certainty and Accuracy in the U.S. Land Use, Land Use Change and Forestry Greenhouse Gas Inventory." https://www.climateworks.org/report/reducing-climate-policy-risk-improving-certainty-and-accuracy-in-the-u-s-land-use-land-use-change-and-forestry-greenhouse-gas-inventory

56 EPA, “Global Non-CO_2 Greenhouse Gas Emission Projections & Mitigation: 2015-2050.” https://www.epa.gov/global-mitigation-non-co2-greenhouse-gases

57 Bloomberg New Energy Finance. Half of U.S Coal Fleet on Shaky Economic Footing. 2018. https://www.bloomberg.com/news/articles/2018-03-26/half-of-all-u-s-coal-plants-would-lose-money-without-regulation

58 Charles Teplin, Mark Dyson, Alex Engel, and Grant Glazer. "The Growing Market for Clean Energy Portfolios: Economic Opportunities for a Shift from New Gas-Fired Generation to Clean Energy Across the United States Electricity Industry." Rocky Mountain Institute, 2019, https://rmi.org/cep-reports

59 U.S. Energy Information Administration. “U.S. Nuclear Generation and Generating Capacity.” Accessed Aug 2019. https://www.eia.gov/nuclear/generation

60 U.S. Department of Energy. “Vogtle.” https://www.energy.gov/lpo/vogtle

61 Paul Picciano, Kevin Rennert, and Daniel Shawhan. “Projected Effects of the Clean Energy Standard Act of 2019.” Resources for the Future.” https://www.rff.org/publications/issue-briefs/projected-effects-clean-energy-standard-act-2019 Full data from the modeling analysis was provided to America’s Pledge offline.

62 "Electric Power Research Institute (EPRI). State Level Electric Energy Efficiency Potential Estimates." 2017.

63 Bruce Tonn, David Carroll, Erin Rose, Beth Hawkins, Scott Pigg, Daniel Bausch, Greg Dalhoff, Michael Blasnik, Joel Eisenberg, Claire Cowan, and Brian Conlon. “Weatherization Works II – Summary of Findings From the ARRA Period Evaluation of the U.S. Department of Energy’s Weatherization Assistance Program.” Oak Ridge National Laboratory, July 2015. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2015_139.pdf

64 Michael Blasnik, Greg Dalhoff, David Carroll, Ferit Ucar, and Dan Bausch. “Evaluation of the Weatherization Assistance Program During Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impacts for Single Family Homes.” Oak Ridge National Laboratory, March 2015. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2014_582.pdf

65 Michael Blasnik, Greg Dalhoff, David Carroll, Ferit Ucar, Dan Bausch, and Daya Bill Johnson. “Evaluation of the Weatherization Assistance Program During Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impact for Mobile Homes.” Oak Ridge National Laboratory, March 2015. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2014_558.pdf

66 David Carroll, Greg Dalhoff, Daya Bill Johnson, Dan Bausch, and Michael Blasnik. “Evaluation of the Weatherization Assistance Program During Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impacts for Multifamily Buildings.” Oak Ridge National Laboratory, January 2015. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2014_583.pdf

67 RA Athalye, B Liu, D Sivaraman, R Bartlett, and DB Elliott. “Impacts of Model Building Energy Codes.” Pacific Northwest National Laboratory, October 2016. https://www.energycodes.gov/sites/default/files/documents/Impacts_Of_Model_Energy_Codes.pdf

68 Sierra Club. Ready for 100 Commitments. https://www.sierraclub.org/ready-for-100/commitments

69 Climate Mayors. http://climatemayors.org

70 Chen, Yan; Liu, Bing; Zhang, Jian; Rosenberg, Michael; Edelson, Jim; Lyles, Mark. “Final Energy Savings Analysis of the Proposed NYStretch-Energy Code 2018.” Pacific Northwest National Lab, December 31, 2018. DOI: 10.2172/1489815.

71 "Model Stretch Code Provisions for a 20% Performance Improvement in New Commercial Construction". New Buildings Institute. https://newbuildings.org/wp-content/uploads/2017/11/20percent_code_provisions_SummaryDoc_FINAL.pdf

72 “Massachusetts Electric and Gas Program Administrators Stretch Code Market Effects Study.” NMR Group, Inc. and Cadmus, March 28, 2017. http://ma-eeac.org/wordpress/wp-content/uploads/Stretch-Code-Market-Effects-Study.pdf

73 National Renewable Energy Laboratory. Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. https://www.nrel.gov/docs/fy18osti/71500.pdf

74 Susie Cagle. "Berkeley became first US city to ban natural gas. Here's what that may mean for the future. The Guardian. https://www.theguardian.com/environment/2019/jul/23/berkeley-natural-gas-ban-environment

75 Grace Hase. "San Jose Approves 'Reach Codes' to Promote Green Development. San Jose Inside. https://www.sanjoseinside.com/2019/09/17/san-jose-approves-reach-codes-to-promote-green-development/

76 https://www.bostonherald.com/2019/11/21/brookline-bans-natural-gas-heating-oil-pipes-for-new-buildings-gas-is-the-past/

77 https://nacfe.org/regional-haul

78 https://eta-publications.lbl.gov/sites/default/files/working_paper_005_battery_electric_trucks_906_0.pdf

79 https://www.forbes.com/sites/alanohnsman/2019/04/14/can-a-15-billion-bet-on-fuel-cell-big-rigs-be-a-game-changer-for-hydrogen/#2a3498f1fe4c

80 https://ww2.arb.ca.gov/sites/default/files/2019-08/190821actpres_0.pdf

81 https://www.fhwa.dot.gov/policyinformation/statistics/2017

82 Mishra, Gouri Shankar, Page Kyle, Jacob Teter, Geoffrey M. Morrison, Sanling Kim, and Sonia Yeh. *Transportation module of global change assessment model (GCAM): model documentation*. No. UCD-ITS-RR-13-05. 2013.

83 McKane, Aimee, Peter Therkelsen, Anna Scodel et al. 2017. Predicting the quantifiable impacts of ISO 50001 on climate change mitigation. Energy Policy 107: 278-288. https://www.sciencedirect.com/science/article/pii/S0301421517302744

84 Lawrence Berkely National Laboratory. "Predicting the Quantifiable Impacts of ISO 50001 on Climate Change Mitigation." August, 2017.

85 Energy Futures Initiative. 2018. "Advancing Large Scale Carbon Management: Expansion of the 45Q Tax Credit." https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5b0604f30e2e7287abb8f3c1/1527121150675/45Q_EFI_5.23.18.pdf

86 Energy Futures Initiative. 2019. Optionality, Flexibility and Innovation: Pathways for Deep Decarbonization in California. https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5ced6fc515fcc0b190b60cd2/1559064542876/EFI_CA_Decarbonization_Full.pdf

87 McKinsey and Company. 2018. Decarbonization of industrial sectors: the next frontier. https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/how%20industry%20can%20move%20toward%20a%20low%20carbon%20future/decarbonization-of-industrial-sectors-the-next-frontier.ashx

88 International Energy Agency. 2018. Technology Roadmap – Low-Carbon Transition in the Cement Industry. https://www.iea.org/newsroom/news/2018/april/cement-technology-roadmap-plots-path-to-cutting-co2-emissions-24-by-2050.html

89 Staff Report: Initial Statement of Reasons. State of California Air Resources Board. https://ww3.arb.ca.gov/regact/2018/casnap/isor.pdf

90 “Alternative Aviation Fuels: Overview of Challenges, Opportunities, and Next Steps.” U.S. Department of Energy. March 2017. https://www.energy.gov/sites/prod/files/2017/03/f34/alternative_aviation_fuels_report.pdf

91 Energy Information Administration (EIA). 2018. Jet fuel consumption, price, and expenditure estimates, 2018. https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_fuel/html/fuel_jf.html

92 Federal Aviation Administration. 2018. National Plan of Integrated Airport Systems (2019-2023). https://www.faa.gov/airports/planning_capacity/npias/reports

93 U.S. Department of Energy. 2016. 2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 448p. doi: 10.2172/1271651. http://energy.gov/eere/bioenergy/2016-billion-ton-report

94 Nature 4 Climate. “US State Mapper.” Accessed Sep 2019. https://nature4climate.org/u-s-carbon-mapper

95 EPA, “Global Non-CO_2 Greenhouse Gas Emission Projections & Mitigation: 2015-2050.” https://www.epa.gov/global-mitigation-non-co2-greenhouse-gases

96 More detail on GCAM 4.1 can be found at: http://jgcri.github.io/gcam-doc/toc.html. The version of GCAM-USA used in this model is based on GCAM X.X.

97 Alvarez et al. 2018. "Assessment of methane emissions from the U.S. oil and gas supply chain." Science. July 13, 2018. https://science.sciencemag.org/content/361/6398/186

98 Bloomberg New Energy Finance, “New Energy Outlook 2018,” https://bnef.turtl.co/story/neo2018

99 EPA. 2018. User’s Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA). Version 3.2.

100 US EIA. Form 860. https://www.eia.gov/electricity/data/eia860

101 EPA. Emissions & Generation Resource Integrated Database (eGRID). https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

102 US EPA. 2019. Air Markets Program. Data. Accessed October, 21 2019. https://ampd.epa.gov/ampd.

103 Williams, J.H., B. Haley, R. Jones (2015). "Policy implications of deep decarbonization in the United States. A report of the Deep Decarbonization Pathways Project of the Sustainable Development Solutions Network and the Institute for Sustainable Development and International Relations." Nov 17, 2015.

104 Risky Business Project. 2016. From Risk to Return: Investing in a Clean Energy Economy. USA: Risky Business.

105 Vignesh Gowrishankar, Amanda Levin. 2017. America's Clean Energy Frontier: the Pathway to a Safer Climate Future. National Resources Defense Council.

106 Cleetus, R., A. Bailie, and S. Clemmer. 2016. The US Power Sector in a Net Zero World. USA: Union of Concerned Scientists.

107 Asia-Pacific Economic Cooperation. 2019. APEC Energy Demand and Supply Outlook 7th Edition Volume II.

108 Haley, B., Jones, R., Kwok, G., Hargreaves, J., Farbes, J.. 2019. 350 PPM Pathways for the United States. U.S. Deep Decarbonization Pathways Project. Evolved Energy Research

109 Burchardt, J. Gerbert, P., Schönberger, S., Herhold, P., Brognaux, C.. 2018. The Economic Case for Combating Climate Change. Boston Consulting Group. https://www.bcg.com/en-us/publications/2018/economic-case-combating-climate-change.aspx

110 National Renewable Energy Laboratory (NREL). Annual Technology Baseline: Electricity. https://atb.nrel.gov

111 Lawrence Berkely National Lab (LBL). Renewables Portfolio Standards Resources. https://emp.lbl.gov/projects/renewables-portfolio

112 U.S. Energy Information Administration (EIA). Annual Electric Power Industry Report, Form EIA-861 detailed data files. https://www.eia.gov/electricity/data/eia861

113 U.S. Energy Information Administration, "Electric Power Annual 2019" https://www.eia.gov/electricity/annual/

114 Bloomberg New Energy Finance, "New Energy Outlook 2018," https://bnef.turtl.co/story/neo2018. Bloomberg New Energy Finance. Half of U.S Coal Fleet on Shaky Economic Footing. 2018. https://www.bloomberg.com/news/articles/2018-03-26/half-of-all-u-s-coal-plants-would-lose-money-without-regulation

115 Moody's. 2019. "U.S. coal's shrinking share of power generation may fall to 11% by 2030." https://www.spglobal.com/marketintelligence/en/news-insights/trending/MShmo4U4USAkqoyf7mEhDw2

116 Institute for Energy Economics and Financial Analysis. 2019. Coal Outlook 2019: Domestic Market Decline Continues. http://ieefa.org/wp-content/uploads/2019/03/Coal-Outlook-2019_March-2019.pdf

117 U.S. Energy Information Administration. "U.S. Nuclear Generation and Generating Capacity." Accessed Aug 2019. https://www.eia.gov/nuclear/generation

118 Paul Picciano, Kevin Rennert, and Daniel Shawhan. "Projected Effects of the Clean Energy Standard Act of 2019." Resources for the Future." https://www.rff.org/publications/issue-briefs/projected-effects-clean-energy-standard-act-2019. Full data from the modeling analysis was provided to America's Pledge offline.

119 Charles Teplin, Mark Dyson, Alex Engel, and Grant Glazer. The Growing Market for Clean Energy Portfolios: Economic Opportunities for a Shift from New Gas-Fired Generation to Clean Energy Across the United States Electricity Industry. Rocky Mountain Institute, 2019, https://rmi.org/cep-reports

120 Energy Futures Initiative. 2018. Advancing Large Scale Carbon Management: Expansion of the 45Q Tax Credit. https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5b0604f30e2e7287abb8f3c1/1527121150675/45Q_EFI_5.23.18.pdf

121 Modeling outputs provided by Environmental Defense Fund (EDF).

122 U.S. Energy Information Administration (EIA). Annual Energy Outlook 2019. https://www.eia.gov/outlooks/aeo/

123 American Council for an Energy-Efficient Economy (ACEEE). 2019 State Energy Efficiency Scorecard. https://aceee.org/research-report/u1908

124 American Council for an Energy-Efficient Economy (ACEEE). https://database.aceee.org

125 U.S. Energy Information Administration (EIA). Annual Electric Power Industry Report, Form EIA-861 detailed data files. https://www.eia.gov/electricity/data/eia861

126 Pacific Northwest National Laboratory (PNNL). Impacts of Model Building Energy Codes. https://www.energycodes.gov/sites/default/files/documents/Impacts_Of_Model_Energy_Codes.pdf

127 Northeast Energy Efficiency Partnership Regional Energy Efficiency Database. https://reed.neep.org/Registration.aspx?Source=https://reed.neep.org/StateDocs.aspx

128 Bruce Tonn, David Carroll, Erin Rose, Beth Hawkins, Scott Pigg, Daniel Bausch, Greg Dalhoff, Michael Blasnik, Joel Eisenberg, Claire Cowan, and Brian Conlon. "Weatherization Works II – Summary of Findings From the ARRA Period Evaluation of the U.S. Department of Energy's Weatherization Assistance Program." Oak Ridge National Laboratory, July 2015. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2015_139.pdf

129 Michael Blasnik, Greg Dalhoff, David Carroll, Ferit Ucar, and Dan Bausch. "Evaluation of the Weatherization Assistance Program During Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impacts for Single Family Homes." Oak Ridge National Laboratory, March 2015. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2014_582.pdf

130 Michael Blasnik, Greg Dalhoff, David Carroll, Ferit Ucar, Dan Bausch, and Daya Bill Johnson. "Evaluation of the Weatherization Assistance Program During Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impact for Mobile Homes." Oak Ridge National Laboratory, March 2015. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2014_558.pdf

131 David Carroll, Greg Dalhoff, Daya Bill Johnson, Dan Bausch, and Michael Blasnik. "Evaluation of the Weatherization Assistance Program During Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impacts for Multifamily Buildings." Oak Ridge National Laboratory, January 2015. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2014_583.pdf

132 National Renewable Energy Laboratory. Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. https://www.nrel.gov/docs/fy18osti/71500.pdf

133 EPRI National Electrification Assessment. http://mydocs.epri.com/docs/PublicMeetingMaterials/ee/000000003002013582.pdf

134 Mai, Trieu, Paige Jadun, Jeffrey Logan, Colin McMillan, Matteo Muratori, Daniel Steinberg, Laura Vimmerstedt, Ryan Jones, Benjamin Haley, and Brent Nelson. 2018. Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-71500. https://www.nrel.gov/docs/fy18osti/71500.pdf

135 Ibid

136 California Air Resources Board. 2019. Terms for Light-Duty Greenhouse Gas Emissions Standards. https://ww2.arb.ca.gov/sites/default/files/2019-07/Auto%20Terms%20Signed.pdf

137 Environmental Defense Fund. Technical Assessment of CO_2 Emission Reductions for Passenger Vehicles in the Post-2025 Timeframe. 2017. https://www.edf.org/sites/default/files/content/final_public_white_paper_post_2026_co2_reductions2.27_clean.pdf

138 International Council for Clean Transportation. Efficiency Technology and Cost Assessment for U.S. 2025-2030 Light Duty Vehicles. 2017. https://theicct.org/sites/default/files/publications/US-LDV-tech-potential_ICCT_white-paper_22032017.pdf

139 Energy Information Administration. 2019. Annual Energy Outlook 2019. https://www.eia.gov/outlooks/aeo

Endnotes

140 U.S. Energy Information Administration (EIA). Analysis of the Effect of Zero-Emission Vehicle Policies: State-Level Incentives and the California Zero-Emission Vehicle Regulations. https://www.eia.gov/analysis/studies/transportation/zeroemissions/pdf/zero_emissions.pdf

141 National Renewable Energy Laboratory. Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. https://www.nrel.gov/docs/fy18osti/71500.pdf

142 https://eta-publications.lbl.gov/sites/default/files/working_paper_005_battery_electric_trucks_906_0.pdf" https://eta-publications.lbl.gov/sites/default/files/working_paper_005_battery_electric_trucks_906_0.pdf

143 https://nacfe.org/regional-haul

144 https://ww2.arb.ca.gov/sites/default/files/2019-08/190821actpres_0.pdf

145 American Council for an Energy-Efficient Economy, https://database.aceee.org

146 U.S. Federal Highway Administration (FWHA). Highway Statistics 2017. https://www.fhwa.dot.gov/policyinformation/statistics/2017/mv1.cfm

147 U.S. Department of Energy (DOE). State & Local Energy Data. https://www.eere.energy.gov/sled/#

148 Aimee McKane, Peter Therkelsen, Anna Scodel, et al. Predicting the quantifiable impacts of ISO 50001 on climate change mitigation. Energy Policy 107. 2017, https://doi.org/10.1016/j.enpol.2017.04.049

149 National Renewable Energy Laboratory. Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. https://www.nrel.gov/docs/fy18osti/71500.pdf

150 Energy Futures Initiative. 2018. Advancing Large Scale Carbon Management: Expansion of the 45Q Tax Credit. https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5b0604f30e2e7287abb8f3c1/1527121150675/45Q_EFI_5.23.18.pdf

151 Tom Land and U.S. Environmental Protection Agency (EPA). "GreenChill Annual Achievements." presented at the Energy & Store Development Conference, September 2017. https://www.epa.gov/sites/production/files/2017-09/documents/gc_recognition.presentation_2017_ceremony.pdf

152 California Environmental Protection Agency, Air Resources Board. "Table B2. Reductions (MMT CO_2E) each calendar year, shown by equipment production year for all emissions sectors covered by proposed regulation," Appendix B: Emission Estimates, https://www.arb.ca.gov/regact/2018/casnap/isorappb.pdf

153 World Resources Institute. CAIT Climate Data Explorer. cait.wri.org

154 EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017." https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017

155 Nature 4 Climate. "US State Mapper." Sep 2019. https://nature4climate.org/u-s-carbon-mapper/

156 Center for Climate and Energy Solutions (C2ES). Regional Greenhouse Gas Initiative (RGGI). https://www.c2es.org/content/regional-greenhouse-gas-initiative-rggi

157 California Air and Resources Board (CARB). AB 32 Scoping Plan. https://ww3.arb.ca.gov/cc/scopingplan/scopingplan.htm

158 EPA, "Global Non-CO_2 Greenhouse Gas Emission Projections & Mitigation: 2015-2050." https://www.epa.gov/global-mitigation-non-co2-greenhouse-gases

159 Disclosure platform for companies, cities, states, and regions, 2017-2019. CDP. https://www.cdp.net/en/data

160 Under2 Coalition, September 2019. The Climate Group. https://www.under2coalition.org/members

161 U.S. State Greenhouse Gas Emissions Targets, September 2019. C2ES. https://www.c2es.org/document/greenhouse-gas-emissions-targets/

162 "Act No. 33-2019 (S. B. 773)." 18th Legislative Assembly of Puerto Rico. http://www.oslpr.org/download/en/2019/A-033-2019.pdf

163 Disclosure platform for companies, cities, states, and regions, 2017-2019. CDP. https://www.cdp.net/en/data

164 Under2 Coalition, September 2019. The Climate Group. https://www.under2coalition.org/members

165 carbonn Climate Registry reporting entities, 2010-2017. ICLEI. https://carbonn.org/

166 State and Local Policy Database, September 2019. ACEEE. https://database.aceee.org/

167 Public announcements for cities and counties include: http://www.bedfordny.gov/wp-content/uploads/2014/05/Climate-Action-Plan-Final.pdf, https://www.bloomingtonmn.gov/pw/energy-action-plan, https://westlinnoregon.gov/sites/default/files/fileattachments/economic_development/page/7619/sustainable_strategic_plan_adopted_12-14-15.pdf, https://www.acgov.org/sustain/documents/climateactionplan_executivesummary.pdf, http://www.co.contra-costa.ca.us/4554/Climate-Action-Plan, http://www.countyofsb.org/csd/asset.c/173, and http://climatechange.westchestergov.com/images/stories/pdfs/GblWrmAction2008FINAL.pdf.

168 Disclosure platform for companies, cities, states, and regions, 2017-2019. CDP. https://www.cdp.net/en/data

169 Companies taking action, September 2019. Science Based Targets. https://sciencebasedtargets.org/companies-taking-action/

170 Public announcements for businesses include: https://www.aboutamazon.com/sustainability/energy-and-environment and https://www.americantower.com/corporate-responsibility/environment.html.

171 Climate Leadership Network, 2017-2019. Second Nature. https://secondnature.org/climate-action-guidance/network/

172 Population and Housing Unit Estimates Tables, 2018. United States Census Bureau. https://www.census.gov/programs-surveys/popest/data/tables.html

173 American Community Survey 5-year Population Estimates, 2013-2017. United States Census Bureau. https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

174 Climate Leadership Network, 2017-2019. Second Nature. https://secondnature.org/climate-action-guidance/network/

175 Gross Domestic Product by State, First Quarter 2019: Table 3 - Current-Dollar Gross Domestic Product (GDP) by State and Region. U.S. Department of Commerce Bureau of Economic Analysis. https://www.bea.gov/news/2019/gross-domestic-product-state-first-quarter-2019

176 "Economic Report to the Governor, 2018: Statistical Appendix." Government of Puerto Rico Planning Board. http://jp.pr.gov/Portals/0/Economia/Apendice%20Estadistico/Ap%C3%A9ndice%20Estad%C3%ADstico%202018.pdf?ver=2019-05-24-180224-817

177 Gross Domestic Product by Metropolitan Area, 2017: Table 1 – Current-Dollar Gross Domestic Product (CDP) by Metropolitan Area, 2012-2017. U.S. Department of Commerce Bureau of Economic Analysis. https://www.bea.gov/data/gdp/gdp-metropolitan-area

178 Market capitalization, September 6, 2017. Bloomberg.

179 Disclosure platform for companies, cities, states, and regions, 2017-2019. CDP. https://www.cdp.net/en/data

180 State Inventory and Projection Tool, August 1, 2019. U.S. Environmental Protection Agency. https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool

181 Puerto Rico Territory Profile and Energy Estimates, August 2019. U.S. Energy Information Administration. https://www.eia.gov/state/data.php?sid=RQ

182 Disclosure platform for companies, cities, states, and regions, 2017-2019. CDP. https://www.cdp.net/en/data

183 State and Local Energy Data (SLED), August 2019. U.S. Department of Energy. https://www.eere.energy.gov/sled

184 Disclosure platform for companies, cities, states, and regions, 2017-2019. CDP. https://www.cdp.net/en/data

185 Climate Leadership Network, 2017-2019. Second Nature. https://secondnature.org/climate-action-guidance/network/

186 Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2017: Table ES-1. U.S. Environmental Protection Agency. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017

187 We Are Still In signatories, September 1, 2019. We Are Still In. https://www.wearestillin.com/signatories

188 Governors, September 1, 2019. United States Climate Alliance. http://www.usclimatealliance.org/governors-1

189 Members, September 1, 2019. U.S. Climate Mayors. http://climatemayors.org/about/members/

190 Population and Housing Unit Estimates Tables, 2018. United States Census Bureau. https://www.census.gov/programs-surveys/popest/data/tables.html

191 American Community Survey 5-year Population Estimates, 2013-2017. United States Census Bureau. https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

192 Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: July 1, 2018. United States Census Bureau. https://www.census.gov/newsroom/press-kits/2018/pop-estimates-national-state.html

193 Gross Domestic Product by State, First Quarter 2019: Table 3 - Current-Dollar Gross Domestic Product (GDP) by State and Region. U.S. Department of Commerce Bureau of Economic Analysis. https://www.bea.gov/news/2019/gross-domestic-product-state-first-quarter-2019

194 "Economic Report to the Governor, 2018: Statistical Appendix." Government of Puerto Rico Planning Board. http://jp.pr.gov/Portals/0/Economia/Apendice%20Estadistico/Ap%C3%A9ndice%20Estad%C3%ADstico%202018.pdf?ver=2019-05-24-180224-817

195 Gross Domestic Product by Metropolitan Area, 2017: Table 1 – Current-Dollar Gross Domestic Product (CDP) by Metropolitan Area, 2012-2017. U.S. Department of Commerce Bureau of Economic Analysis. https://www.bea.gov/data/gdp/gdp-metropolitan-area

196 Gross Domestic Product by State, First Quarter 2019: Table 3 - Current-Dollar Gross Domestic Product (GDP) by State and Region. U.S. Department of Commerce Bureau of Economic Analysis. https://www.bea.gov/news/2019/gross-domestic-product-state-first-quarter-2019

197 Disclosure platform for companies, cities, states, and regions, 2017-2019. CDP. https://www.cdp.net/en/data

198 State Inventory and Projection Tool, August 1, 2019. U.S. Environmental Protection Agency. https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool

199 Puerto Rico Territory Profile and Energy Estimates, August 2019. U.S. Energy Information Administration. https://www.eia.gov/state/data.php?sid=RQ

200 Disclosure platform for companies, cities, states, and regions, 2017-2019. CDP. https://www.cdp.net/en/data

201 Public announcements for cities include: https://www.sandiego.gov/sites/default/files/appendix_for_2017_annual_report.pdf

202 State and Local Energy Data (SLED), August 2019. U.S. Department of Energy. https://www.eere.energy.gov/sled

203 Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2017: Table ES-1. U.S. Environmental Protection Agency. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017