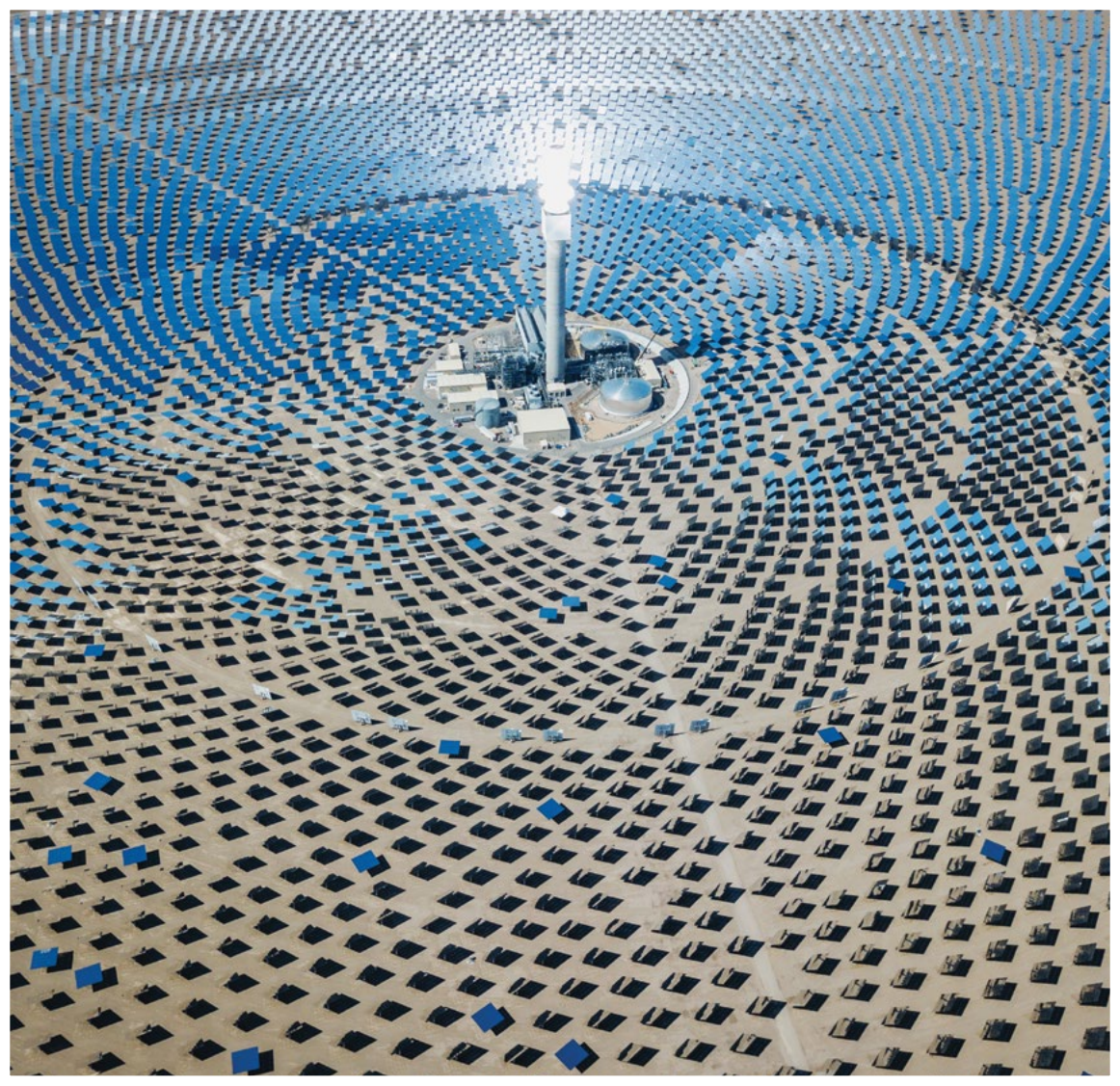
FULFILLING AMERICA'S PLEDGE

How States, Cities, and Businesses Are Leading the United States to a Low-Carbon Future



Technical Appendix

Methodologies and Assumptions to Quantify the Greenhouse Gas Implications of City, State, and Business Action

Contents

Chapter 1: Introduction

In July 2017, Michael R. Bloomberg and Governor Edmund G. Brown, Jr. launched *America's Pledge*, a new initiative to analyze, motivate, and raise ambition for actions of states, cities, and businesses in the U.S. to drive down their greenhouse gas (GHG) emissions, consistent with the goals of the Paris Agreement. In November 2017, the first *America's Pledge* report was released, which emphasized the importance of contributions from states, cities, and businesses in achieving our national climate goals.

A new 2018 report, *Fulfilling America's Pledge: How States, Cities, and Businesses Are Leading the United States to a Low-Carbon Future,* (the report that this technical appendix supports), has three goals grounded in a deeper analysis of current and potential future actions: to *assess the impact* of these actions in 2025 and beyond, *to support increased ambition* from these "real economy" actors in the U.S., and to *understand the pathway to long-term decarbonization*. To support these three objectives, the *Fulfilling America's Pledge* report delivers a robust analysis of current and potential future climate commitments and actions of real economy actors in the U.S., and the extent to which these actions keep the U.S. on a trajectory toward deep decarbonization. This technical appendix provides a detailed description and discussion of this analysis.

The best practice methods for collecting, aggregating, and modeling the collective impact of real economy and country-level action on national emissions trajectories are evolving quickly. Because the cycle of ambition in the Paris Agreement is based on the ability of countries and real economy actors to understand and scope ambitious action, these evolving analytical methodologies 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 real economy actors.

Understanding the implications of real economy actions requires grappling with a multitude of possible actions along with the fact that these actions can overlap and interact with one another in multiple ways. *Fulfilling America's Pledge* takes on this challenge, combining tools and analytical strategies to quantify the impact of actions by real economy actors. This technical appendix provides detailed information on the methodology used in *Fulfilling America's Pledge*.

Chapter 2: Overview of Analytical Approach

The analytical approach for *Fulfilling America's Pledge* follows three main steps: (1) we tallied scope and scale of individual climate commitments; (2) we aggregated the impact of those commitments along with potential additional actions by real economy actors at the sector level; and (3) we projected the impact of those commitments and additional actions on economy-wide GHG emissions. We 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 policies, commitments, and actions—both by the federal government and real economy actors.
- A ***Climate Action Strategies*** scenario that includes a specific menu of 10 high-impact, near-term action opportunities that real economy actors can execute in collaboration.
- An ***Enhanced Engagement*** scenario that explores the potential for additional ambitious action by real economy actors.

The first step in the analytical process was a "footprint analysis" that estimates the scale of current coalitions of real economy actors and their commitments, measured in terms of the share of national economic activity, population, and current GHG emissions of the actors in those coalitions. This component of the research largely focused on providing an update to a similar footprint analysis from the *America's Pledge Phase I Report* on the scale and scope of U.S. real economy actions supporting the Paris Agreement. We compiled and quantified actions 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 results of this footprint analysis are presented in Chapter 1 and in the GHG Reduction Targets section of Chapter 2 of the report, *Fulfilling America's Pledge*.

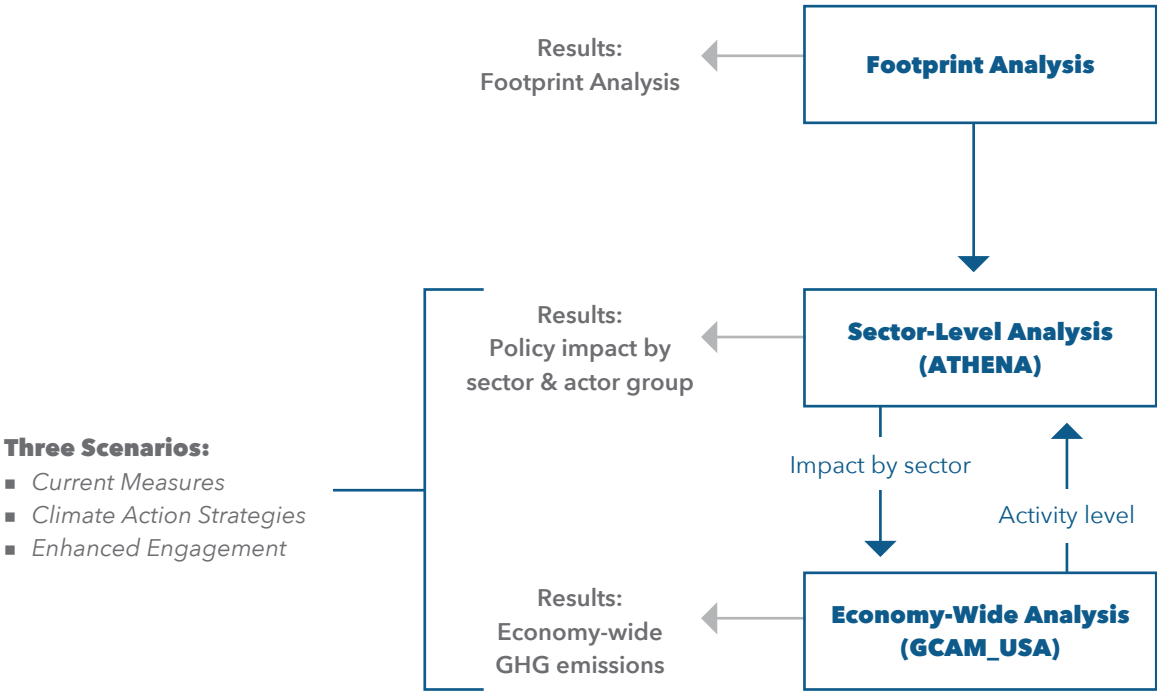
Second, we estimated the impacts of current commitments, along with the impacts of the *Climate Action Strategies* and *Enhanced Engagement* scenarios, and aggregated those impacts at the sector level. At this step in the analysis, we measured activity data appropriate to the sector, for example, TWh of renewable generation, number of zero-emission vehicles sold, or HFC emissions. To understand the combined effects of different actions while more explicitly considering their interactions and avoid double counting within each sector, we developed a new model, the Aggregation Tool for modeling Historic and Enhanced Non-federal Actions (ATHENA). The sector-level analysis made use of historical emissions data, activity data, and policy or target information from a range of data sources, including EIA's State Energy Data System (SEDS), WRI's Climate Analysis Indicators Tool (CAIT), the U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) Highway Statistics Series, the National Renewable Energy Laboratory (NREL) State and Local Energy Data (SLED) database, the Global Change Assessment Model (GCAM), the Database of State Incentives for Renewables & Efficiency (DSIRE), the American Council for an Energy-Efficient Economy (ACEEE) state and city policy databases and scorecards, the Carbon Disclosure Project (CDP), various coalitions (like Sierra Club's Ready for 100), and state and city action plans, among others. The sectoral analyses and ATHENA phase of our approach feeds into the *Current Measures* scenario in Chapter 2, and the *Climate Action Strategies* and *Enhanced Engagement* scenarios in Chapter 3 in *Fulfilling America's Pledge*.

As a final step, we estimated the economy-wide GHG emissions impacts of the three scenarios. This was accomplished using the U.S.-specific version of GCAM (GCAM-USA). GCAM is an open-source, integrated, economy-wide modeling tool that can be used to assess the energy, land, and

emissions implications of actions such as those in *Fulfilling America's Pledge*. Information from the sectoral analysis in the second step served as input to the assessment of economy-wide impacts using GCAM-USA. The use of this integrated framework allowed exploration of interactions between sectors, including global interactions, and eliminated double counting across the U.S. economy. The results of the economy-wide analysis are presented in Chapter 4 of *Fulfilling America's Pledge*.

A core feature of this 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, non-CO_2 emissions by source, and growth forecasts. This information was then processed and adjusted in ATHENA to represent the impacts within each sector of sub-national policies and commitments from one scenario to the next. These impacts were then converted into sector-appropriate metrics at the state 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 provided consistent characterization of sectoral and national emissions trajectories based on varying levels of real economy ambition.

Figure 1. Analytical strategy for America's Pledge 2018 Report, *Fulfilling America's Pledge*



How Fulfilling America's Pledge compares to other bottom-up analyses

The analysis supporting *Fulfilling America's Pledge* is the most comprehensive exploration to date of the economy-wide implications of mitigation actions by real economy actors in the U.S. It builds on a set of previous studies that also estimate the impact of real economy actions in the development of future scenarios. A variety of approaches have been used within these studies.

Serving as a basis for many analyses and a stand-alone depiction of projected emissions in its own right, the U.S. Energy Information Administration's *Annual Energy Outlook* (AEO) currently includes many state and federal policies. This includes, for example, federal production and investment tax credits (PTC and ITC), state renewable portfolio standards (RPS), power sector emissions caps through the Regional Greenhouse Gas Initiative (RGGI), and transportation fuel taxes and standards.[1] AEO is developed using the National Energy Modeling System (NEMS), an integrated model that captures interactions of economic changes and energy supply, demand, and prices.[2] Notably, AEO does not include non-energy CO_2 emissions sources such as F-gases, fugitive methane, or Land Use, Land-Use Change and Forestry (LULUCF). In addition, AEO does not include many real economy actions, nor does it include analysis of potential additional actions that real economy actors might take to increase their ambition.

Taking a more comprehensive approach, Rhodium's *Taking Stock* (2018) relies on a modified version of NEMS, RHG-NEMS, and includes non-CO_2 sources along with estimates of LULUCF.[3] *Taking Stock* includes some policies not included in AEO, such as state-level Energy Efficiency Resource Standards (EERS). *Taking Stock* does not include city or business level commitments, nor any actions such as targets that are not already backed by binding policy.[4]

Greenblatt and Wei's *Assessment of the climate commitments and additional mitigation policies of the United States* (2016) covers an array of policies to reduce energy and non-energy emissions.[5] These include some federal policies that have since been vacated or whose legal status is now uncertain, including the Clean Power Plan and Significant New Alternatives Policy (SNAP) to reduce HFC emissions. In contrast to the above approaches, the analysis also models potentially more ambitious scenarios by categorizing policies into three categories: passed legislation; proposed legislation; and announced targets, potential policies, or voluntary measures. The study uses AEO emissions projections for energy CO_2 sources and projections from the First and Second U.S. Biennial Reports to the UNFCCC for other emissions sources. With a few exceptions (e.g. state building codes), the study focuses largely on federal-level actions.

The report "*States, cities and businesses leading the way: a first look at decentralized climate commitments in the US",* produced collaboratively by Yale, PBL-Netherlands, and the New Climate Institute, takes a more targeted approach by focusing on two specific types of non-state actions – GHG emissions reduction targets and renewable

energy targets – and estimating the impact of these goals in aggregate while controlling for overlap and double counting.[6] The approach incorporates targets across four levels of action: states, cities, energy end-use companies, and energy supply companies (e.g. electric utilities). The analysis then integrates these impacts with a "current administration policies" scenario derived from Climate Action Tracker (CAT), which is itself a synthesis of EIA's AEO and the Second U.S. Biennial Report (and thus covers energy and non-energy CO_2 emissions sources).[7] This same research group released a new report, *Global climate action of cities, regions and companies: Individual actors, collective initiatives and their impact on global greenhouse gas emissions*, in August 2018 that estimates the impact of non-state actions globally and in specific countries, including the U.S.

In comparison to these previous studies, several key features of the analytical methodology supporting *Fulfilling America's Pledge* are as follows:

- *Estimation of increased ambition through three scenarios*. While some approaches focus only on the impact of current policies and commitments, we analyze models the projected impact of current policies (which we call *Current Measures*), a subset of not-yet-enacted but feasible future actions (*Climate Actions Strategies*), and a depiction of the broader potential of fully-engaged real economy actors within the limits of economic and technical potential (*Enhanced Engagement*).
- *Comprehensive GHG coverage with LULUCF*. Whereas many existing resources do not incorporate the full range of emissions sources (including Climate Action Tracker[8] in addition to those mentioned above) our analysis includes all major gas and LULUCF categories.
- *Transparent inclusion of sub-national policies*. Our analysis covers policies from federal as well as state and city levels and business initiatives, and it reports aggregation methods used in the sector-specific sections of this technical appendix. While other analyses cover such policies to varying degrees, some do not provide explicit discussion of how they incorporated such policy impacts, and others may not directly incorporate city policies or commitments in their analyses at all (Greenblatt and Wei, 2016; Rhodium Group, 2018).
- *Inclusion of broad range of sectoral climate measures:* Other analyses aggregating the impact of state, city, and business actions to-date have often focused on one or two prominent types of actions, such as GHG targets or renewable energy procurement targets (NCI, 2017). Our analysis, in contrast, assesses impact across a broad array of sources and economic sectors – for example, renewables, efficiency, transportation, methane, hydrofluorocarbons (HFCs) – and thus allows for more comprehensive, sector-by-sector assessment.

Principles of Analysis

The analysis supporting *Fulfilling America's Pledge* is constructed first and foremost to be robust, to employ sound methodologies, and to advance the field of practice in the area of integrating real economy action into scoping national and global ambition. In addition, the analysis is focused on appropriately reflecting contributions of real economy actors and helping clarify the scale of current and potential actions in the U.S. As we carried out this project, we developed the following principles for such analysis, based on existing good practice and the goals of America's Pledge. We aimed to follow those principles whenever possible throughout the analysis.

1. *Specify boundaries of assessment.* Reports which measure contributions, pledges, or potential from a portion of an economy should specify what is and is not covered. For example, if a report measures how much cities could reduce emissions in buildings and public transportation, but not in carbon intensity of fuel or electricity, results should be clearly labelled "potential reductions from buildings and transport in cities" rather than "potential emissions reductions from cities."

2. *Distinguish sample vs. universe.* Similarly, if a network is reporting on the commitments of its city members, but many cities do not belong to the network, this should be labeled clearly, for example as: "climate actions pledged by X cities in Y network," and not "climate actions pledged by North American cities."

3. *Use clearly defined metrics for samples.* If reporting on a sample of a sector only, avoid when possible using metrics that can be easily confused as applying to the universe of actors. For example, use percentage progress projected, rather than absolute tons, to the sub-sample results being described as applying to the full sector.

4. *Leave narrative space for additional ambition.* Maximizing real economy action requires greater empowerment of cities, businesses, and states. Analysis may show that current actions may be inadequate to address climate challenges. The analysis and presentation of results should therefore provide information that could inform enhanced actions.

5. *Communicate the distinctions between levels of commitment and/or implementation.* Analyses should distinguish between legally binding or actively fulfilled commitments, on the one hand, and aspirational but not yet committed goals on the other.

6. *Test sensitivities to alternate assumptions about external drivers.* Projections of future economy-wide emissions should always offer a range, rather than a single reference case scenario. Economy wide projections depend on variables like economic growth or energy prices – variables not controlled by climate action alone – which can swamp and obscure the impact of alternative emissions reduction pathways. Readers should be kept aware

of these uncertainties by being offered a range, not a single number, as the projected outcome.

7. *Distinguish between estimation method and responsibility/credit*. Many actions can be mandated by one entity and implemented in part by another. This creates the possibility of double counting, which must be avoided in reporting potential reductions. But in the world of action and politics, it is completely fair for more than one entity to share credit for actions. For example, when a firm commits to 100% renewable energy that is supported by federal renewable energy incentives and that could help achieve a city goal and a state Renewable Portfolio Standard (RPS) goal, all four of these entities ought to be acknowledged. Thus, *for purposes of recognizing responsibility or credit*, when a given emission reduction is overdetermined – in this example, by federal incentives, a state renewable energy mandate, and a city or corporate clean energy purchasing requirement – the reduction should not be arbitrarily assigned to one action level but be credited to all entities who mandated it. Removing double counting can then take place in aggregating the cumulative impact of national, state, city, and business actions.

Chapter 3: Footprint Analysis

The first step in the analysis measures the scope and scale of coalitions of real economy actors in the United States who are either members of coalitions supporting the Paris Agreement or who have established GHG targets. This analysis shows the footprint of the actors in those coalitions, in terms of their share of national economic activity, population, and current GHG emissions, providing an update of similar analysis included in the *America's Pledge Phase I* Report in 2017. The results of the footprint analysis can be found in Chapters 1 and 2 of *Fulfilling America's Pledge*.

A similar approach to this analysis is taken for both the real economy actors and the coalitions supporting the Paris Agreement. First, the actors in each category are identified and counted. Population numbers come from U.S. Census estimates for states, cities and counties, with double counting across the categories addressed by only adding in counties outside of included states; and then only adding in cities outside of included states and counties. A similar approach is used for gross domestic product (GDP) and current GHG emissions for states, cities and counties. GDP data are derived from the U.S. Bureau of Economic Analysis (BEA). GHG emissions data come from CDP when available; from WRI's CAIT Climate Data Explorer or the EIA when not available through CDP. More details on data sources and the steps taken in this analysis are provided in Appendix B of this technical appendix.

Chapter 4: Sectoral Analysis

The second step in the analysis was the development of estimates of the sectoral implications of the three scenarios in this study: *Current Measures*, the 10 *Climate Action Strategies*, and *Enhanced Engagement*. This chapter discusses the process of developing these estimates.

This section provides an overview of ATHENA, used for the bottom-up estimation of policy impacts by sector. These sectoral impacts are measured with activity data appropriate to the sector, for example, terawatt hours (TWh) of renewable generation, number of zero-emission vehicles sold, or HFC emissions. We then summarize how estimates were developed beyond *Current Measures* to project increased ambition at the sector level. Sector-specific methods are then discussed, detailing the way that each sector in the three scenarios was implemented in ATHENA or was otherwise constructed to be consistent with the overall sector-level analysis. While the majority of sector-specific impacts were generated using ATHENA, for certain sectors estimates were generated in a more top-down fashion without explicit consideration of overlap across different actors and actions. These exceptions are described in more detail below.

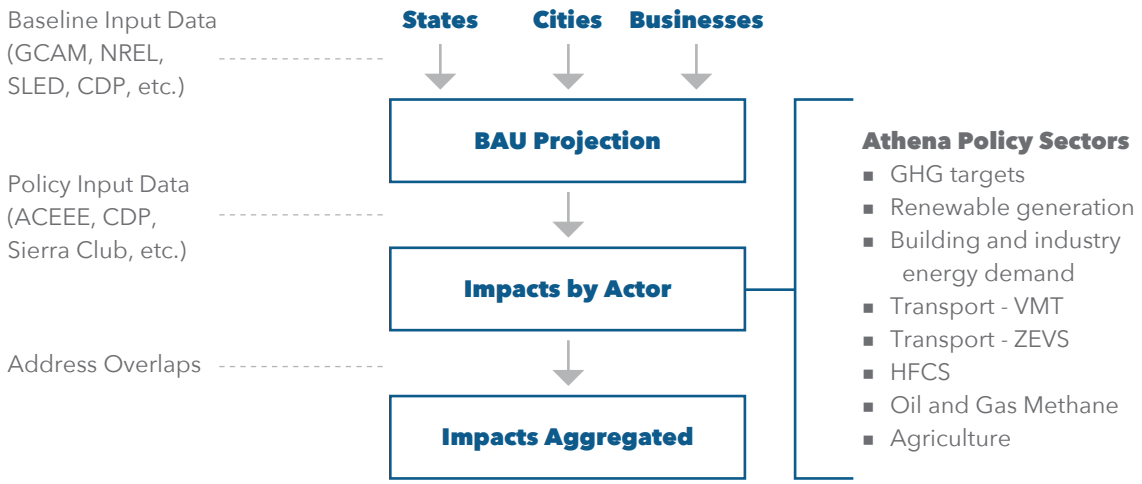
The outputs of the sectoral analysis and modeling are found in Chapters 2 and 3 of *Fulfilling America's Pledge*. The subsequent sections only describe methods and assumptions relied upon to establish the universe of actions and estimate sector-specific impacts by sector, prior to being modeled in GCAM, and thus do not represent the integrated modeling assumptions used to generate economy-wide GHG reduction estimates.

> *Note: the term "sectors" as used in this phase of the analysis and in the subsequent sections of this appendix is meant to indicate policy areas in which real economy- actor 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 Fulfilling America's Pledge report.*

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 are taking actions in cities that have their own suites of policies, and city and business actions are in turn taking place in states with policies that have overlapping goals. When modeling the impact of policies and commitments, we needed to control for this overlap. To overcome this, WRI developed a new tool, ATHENA, to integrate state, city and business actions and aggregate the net contribution of policies and commitments at the sector level. The tool is a series of sector-specific models, each of which shares common underlying assumptions regarding policy interactions and overlap, which are described in the sections below. Figure 2 summarizes the different sectors modeled in ATHENA and the tool's overall analytical flow.

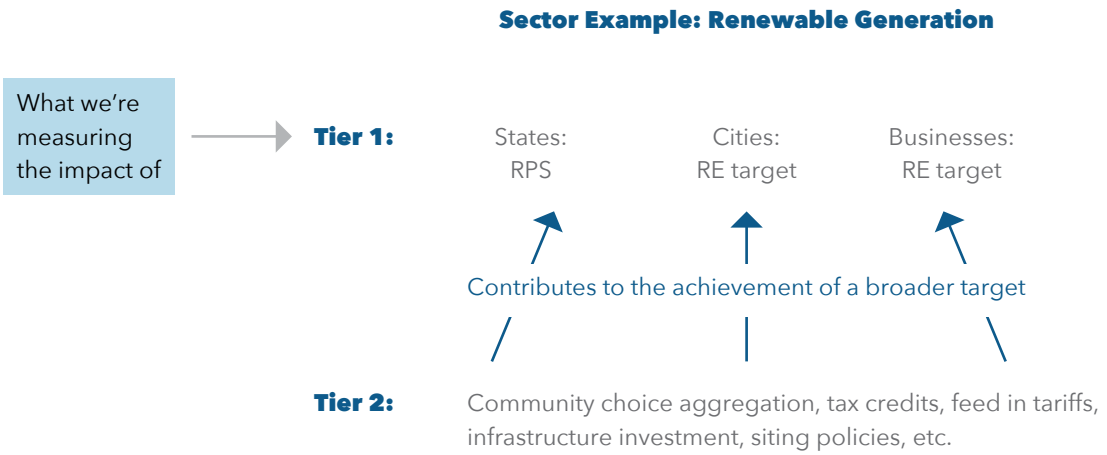
Figure 2. ATHENA Modeling Flow



POLICY TIERING

A first issue in aggregating actions is an assessment of the level at which policies should be modeled. For example, a state may have a renewable energy target that is characterized in terms of a percentage of total generation to be provided by renewable sources. It may then have a set of specific policies or approaches to implement this target, such as tax credits, feed in tariffs, infrastructure investment, community choice aggregation, etc. For this analysis, we constructed a policy tiering approach that allows us to define at which of these levels we will be modeling impact. Tier 1 policies are generally those at the higher level, for example, a renewable electricity target. Tier 2 policies are the granular measures that are used to achieve these targets (See Figure 3 below). Our general approach was to quantify Tier 1 policies rather than the Tier 2 actions.

Figure 3. Tier 1 and Tier 2 Actions



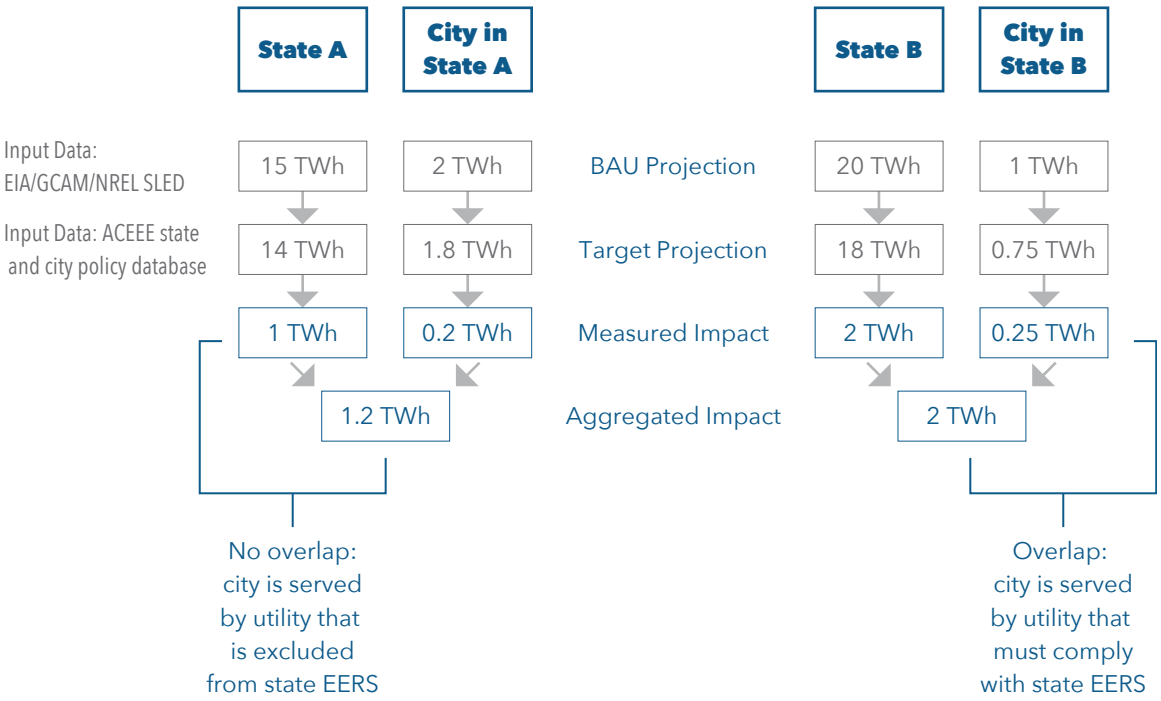
While Tier 1 actions may often subsume actions characterized as Tier 2, this is not always the case. For example, significant infrastructure investment or local siting policies may occur within regions or communities without top-down tier 1 targets, but which nonetheless will lead to increased renewable generation. Therefore, a limitation of our approach is that it does not capture the full impact of all possible actions in the real economy in cases in which we miss actions due to the tiering approach. As the field of sub-national policy modeling continues to develop, future iterations 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-tier policies along with top-down targets can become exceedingly complex, and 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 TYPES OF ACTORS

A second challenge in aggregating real economy actions is that policies at the state, city, and business level overlap within a given sector. In this analysis, we first estimated the full impact of a given policy by each type of actor in a given sector. 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. 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 and are detailed in the sections below.

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 in Figure 4 below.

Figure 4. Accounting for overlap across levels of action



In this example, two states (State A and State B), have energy efficiency targets that would result in 1 TWh and 2 TWh of energy savings, respectively. In addition, 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 region that must comply with the state goal and thus overlap is 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 the ATHENA analysis. 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 the footprint analysis, not all were aggregated with state and city impacts and modeled in ATHENA. For example, data on corporate renewable energy targets were quantified and described in the narrative of the report but not aggregated together with city and state actions and incorporated into the ATHENA analyses. 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. For many types of corporate action, available information does not specify the location (e.g., facility) where action was taken, making it difficult to fold into a geographic aggregation at the state level. Details on which actors and actions were included in the *Current Measures* scenario are included in Table 2 of the "*Inputs and Assumptions for the Current Measures Scenario*" section below.

EXISTING VS. PLEDGED ACTIONS

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

1. Existing actions: Actions that are have been formally adopted by local and regional governments, are legally binding, and which are currently being implemented. These include legislation adopted in statehouses and ordinances approved by city councils.
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 a clear indication of implementation to date. These may include executive orders, mayoral announcements, or voluntary corporate commitments.

Table 1 below 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 chapter.

Table 1. Examples of existing vs. pledged policies and actions

Category	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		
Voluntary program (e.g. Gas Star)		x

These two categories allow for flexibility both from a modeling and a narrative standpoint in the *Current Measures* scenario. The scale of actions and their projected impact can be assessed through multiple lenses (e.g., legally binding actions only or combined with pledged goals). It is important to note that ATHENA results presented in *Fulfilling America's Pledge* for the *Current Measures* scenario include both existing and pledged actions. Also, the categories were not used to explicitly discount impact of certain types of policies or indicate the likelihood of certain policies being implemented, but rather served to add further dimensionality to the analysis and report. For some sectors, the distinction is shown in the *Fulfilling America's Pledge* report for the purposes of adding relevant context; however, in other cases, results are simply shown in aggregate, and relative contributions of existing or pledged actions are not presented separately. For all sectors, details on how measures were categorized are included in the sections below.

INTERACTIONS WITH GCAM

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

With few exceptions, the initial data from GCAM are generally interpreted in ATHENA as a no-policy, reference scenario in which sub-national policies, and some key federal policies, are not represented. Thus, the full impact of policies is applied to the baseline projections without need for addressing overlap. Exceptions to this assumption and cases where any sub-federal policies are embedded in the baseline are discussed by sector below. Further details on GCAM-specific assumptions can also be found in Chapter 5 of this technical appendix.

The GCAM reference case scenario does, however, already 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 modeling results in ATHENA typically represent the impact of real economy actor policies only, final modeling results from GCAM account for the combined impacts of these federal-level policies and the real economy impacts from ATHENA. More details on how these policies are integrated can be found in Chapter 5 of this technical appendix.

In addition, three federal policies not already included in GCAM with impacts on the sectors modeled were explicitly modeled in ATHENA and aggregated with real economy actions before being transferred back to GCAM. These were the U.S. Environmental Protection Agency (EPA) Section 608 refrigerant management policy for HFCs, the federal New Source Performance Standards (NSPS) in the oil and gas sector, and current Bureau of Land Management (BLM) rules in the oil and gas sector, all of which were still in place as of August 2018. These policy impacts were aggregated together using the same general methods described above, with the addition of federal impacts at an additional, higher level of action. 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.

Finally, aggregate policy impacts in ATHENA (i.e., the combined impact of all actors within a policy sector) are ultimately summed to the state-level before being fed back to GCAM. This ensures consistency in terms of the geographic level at which data is transferred, as initial GCAM inputs are also at the state level.

ESTIMATING INCREASED AMBITION

The preceding sections largely cover the manner in which policies are modeled in ATHENA to establish a *Current Measures* scenario at the sector-level. However, a key feature of the analysis presented in *Fulfilling America's Pledge* is the presentation of not just the impact of current actions on the part of real economy actors, but also the potential impact of increased ambition envisioned in the *Climate Action Strategies* and *Enhanced Engagement* scenarios. Establishing these scenarios in ATHENA typically involved relying on the *Current Measures* impacts as baseline from which to model increased ambition, with impacts modeled in one scenario being additive to those of the preceding scenario.

For each sector, specific assumptions were made (described in more detail in the sections that follow) regarding the extent to which the impact of real economy actors could be increased. Taking the renewable energy sector as an example, for the *Climate Action Strategies* scenario a subset of states with RPS policies expiring in 2020 were assumed to extend and increase their programs through model year 2025. In addition, a discrete set of cities with commitments to clean energy were assumed to adopt explicit targets by model year 2020 and achieve linear progress toward their goals, thus further driving new renewable energy generation. These assumed actions were assumed to overlap according to the same logic established in the *Current Measures* scenario. Aggregated impacts – which represent the

increased ambition as well as the baseline ambition from the *Current Measures* scenario – are then fed to GCAM for the economy-wide modeling of the *Climate Action Strategies* scenario.

For most sectors, the scenarios representing *Climate Action Strategies* and *Enhanced Engagement* were built off the bottom-up up aggregation of policies in the *Current Measures* scenario, however there were some notable exceptions where assumptions were developed in a more top-down fashion. These include assumptions regarding building electrification, nuclear fleet retention in the power sector, and land-sink increases. The modeling of impacts in these sectors did not involve a bottom-up accounting of policy impacts and overlap in ATHENA, however they still represent important components of the overall sectoral analysis that then fed into the economy-wide modeling described in Appendix A. More details on assumptions for both ATHENA and non-ATHENA sectoral inputs to the three scenarios are described below.

Inputs and Assumptions for the *Current Measures* Scenario

OVERVIEW OF APPROACH

The *Current Measures* scenario is the foundational scenario for the America's Pledge analysis, providing a depiction of how far current sub-national policies can take the U.S. in terms of sector-specific impacts. The following sections each detail the process of modeling a specific policy included in the scenario – at the state, city, and possibly corporate level – and then provides 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 corporate climate action interact for that policy type.

IDENTIFYING CURRENT POLICIES AND TARGETS

The America's Pledge Phase I Report highlighted 30 state policies, 20 city policies, and 10 corporate policies that real economy actors already have in place.[9] These lists were used as a starting point for selecting the *Current Measures* to be analyzed using a bottom-up modeling approach, and were supplemented with a review of the policy and action areas described below. The evaluation process for inclusion in the *Current Measures* scenario included the following general steps: (1) differentiating between sector-specific actions and economy-wide GHG targets; (2) identifying where the impact of sector-specific policies and actions could overlap; and (3) differentiating between existing actions and pledges across all 50 states, the cities that represent the largest 285 metropolitan areas, and a broader set of businesses.[10] These steps are discussed in more detail in the sections that follow.

Table 2 below summarizes the policies identified for the bottom-up aggregation analysis feeding into the *Current Measures* scenario. In some cases, policies at certain levels were not included due to a lack of data or actual actions at a given level (for example, no known city-level action on HFCs was identified). These cases are marked in the table below as "not included." In other cases, data were collected and impacts were estimated for certain policies or actions, however they were ultimately not included in the broader modeling of the scenario due to data limitations or a conscious decision not to include various categories of actions. These cases are marked in the table below as "quantified but not modeled." All other policies described in the table below are included in the *Current Measures* scenario.

Table 2. Summary of Policies & Targets included in *Current Measures* scenario

Category	State	City	Business
GHG targets	Economy-wide GHG target (quantified but not modeled)	Economy-wide GHG target (quantified but not modeled)	Economy-wide GHG target (quantified but not modeled)
GHG binding caps	RGGI caps and California AB32 & SB32	Not included	Not included
Renewables	RPS	Renewable (RE) target	RE target (quantified but not modeled)
Building & Industry energy demand	EERS	EE target	Not included
Transportation	ZEV mandate, municipal fleet target, VMT target	Municipal fleet target, VMT target	Not included
HFCs	CA SNAP, CA refrigerant mgmt. standards	Not included	Reductions reported through EPA GreenChill program
Oil & gas systems	Existing equipment standards	Not included	Reductions reported through EPA Natural Gas STAR program
Agriculture	Not included	Not included	Reductions reported through AgSTAR program

In the case of GHG targets not backed by a cap or pricing mechanism, estimates of aggregate impacts were produced and are described in the narrative of *Fulfilling America's Pledge*, however the analytical team decided not to include them in the *Current Measures* scenario in order to model a more conservative depiction of current impacts from real economy actors. While such GHG reduction targets are undoubtedly a vital policy mechanism, they are effective only if they have strong implementation plans (including monitoring, reporting, and verification) and are backed with underlying policies, such as cap-and-trade, clean energy standards, methane standards, vehicle emissions mandates, and other policies discussed in forthcoming sections. It is these underlying policies, rather than top-down GHG targets, that are explicitly modeled in the *Current Measures* scenario.

Overall, our identification and aggregation process for the *Current Measures* scenario 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 relevant actions (see the preceding section on policy tiering).
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 preceding section on existing and pledged actions).
5. Estimated the baseline scenario, taking into account the effect of any embedded existing policies.
6. Calculated the impact for each actor group.

7. Aggregated the impact across actors within each sector, taking into account overlapping impact.

This approach 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,[11] the Global Covenant of Mayors Emission Scenario methodology,[12] and the Greenhouse Gas Protocol Mitigation Goal Standard and Policy and Action Standard.[13]

SECTOR-SPECIFIC METHODS AND ASSUMPTIONS

GHG Emission Reduction Targets

Two legally-binding emissions cap regimes, California's economy-wide AB32 and SB32 GHG emission reduction standards and the power sector CO_2 cap-and-trade program implemented by the nine Northeastern states through RGGI, are included in the GCAM baseline and thus incorporated in the *Current Measures* scenario by default.

GHG emission reduction targets that have been adopted by states, cities, and businesses that do not have a carbon price (tax or cap-and-trade program) were also included in the sectoral analysis. However as previously mentioned, in order to keep our depiction of current impact from real economy actors conservative, these targets were not included in the modeling of the Current Measures scenario. Despite this, the process of data collection and impact aggregation mirrored that of the other sectors included in the scenario, and is thus described below.

STATE GHG EMISSION REDUCTION TARGETS

At the state level, we estimated the impact of 21 economy-wide GHG targets. Twelve of these have been adopted by state legislation while six are executive orders and three are non-codified goals publicly expressed by governors or through climate action plans. Target information was obtained from the Center for Climate and Energy Solutions (C2ES) state policy database.[14] Because the C2ES data was compiled in 2016, we reviewed state-specific information to update targets and include a more recently enacted target in Delaware. We obtained baseline GHG emission values from GCAM's estimates. We then applied GHG reduction targets on a linear trend from 2016 to the target year and between target years, if the state has GHG targets for more than one year. For any targets that end before 2030, we assumed that the state will hold GHG levels constant from the target year forward.

CITY GHG EMISSION REDUCTION TARGETS

At the city-level, we estimated the impact of 115 GHG targets, obtained from ACEEE's local policy database, the Under2 Memorandum of Understanding (MOU), CDP, the carbon*n Climate Registry (cCR), and the Chicago Climate Charter.*[15] We obtained historical GHG emissions estimates for cities from the SLED tool.[16] These estimates only include energy sector emissions (residential, commercial, industrial, and on-road transport emissions) for the year 2013. To estimate emissions for years prior to 2013 and for the years 2014-2016, we use state-level trends from GCAM's state energy GHG emissions. As with the state-level targets, we assume linear reductions from 2016 to the target year and between target years, if the city has GHG targets for more than one year. For any targets that end before 2030, we assume that the city will hold GHG levels constant from the target year forward.

CORPORATE GHG EMISSION REDUCTION TARGETS

At the business level, we estimated the impact of 155 GHG targets, obtained from CDP's database, developed as part of the ICAT aggregation effort.[17] This database contains GHG target information,

including base year emissions levels, target year, scope of emissions covered, and whether the target is location-based or market-based. This database also contains estimates developed by CDP of the GHG impact of each company's reduction target in their target year. For purposes of this analysis, we focused on measuring the impact of absolute, scope 1 & 2 location-based targets for all non-utility businesses in 2025.[18] We assumed that once a company's target is achieved, the company continues to achieve the same of abatement going forward. We relied on baseline emissions for each company as reported in the CDP database, after accounting for the share of emissions occurring within the U.S., according the reported country-specific breakdown of scope 1 & 2 emissions.

REAL ECONOMY AGGREGATION

We summed up all the city GHG reductions and compared them to state GHG commitments. We assume that city GHG reductions would contribute to achieving their state's target, but any reductions beyond those attributable to state-level actions are counted as additional. For instance, if a city has a GHG goal but a state does not, the full city GHG target is assumed to be "additional." Likewise, if the aggregate impact of the GHG goals established by cities located in the same state result in a larger impact compared to the state's impact, the increment of the city goals over the state goals would be additional. But, if a state's city commitments amount to less GHG abatement than the state goal, the city goal(s) are assumed to not contribute any GHG reductions beyond the state target. Because we were unable to downscale the impact of corporate GHG targets to specific cities or states, we did not attempt to aggregate the impact of corporate GHG targets with state and city GHG impacts.

Coal Retirements

The *Current Measures* scenario assumes that all coal units that have announced retirement will retire at their scheduled date through 2030. In addition to these, 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) would likely retire by 2025 and some additional uneconomic units in regulated markets by 2030. For 2025, the analysis assumes that units in deregulated markets that had net negative long-run margins for at least 5 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."[19] BNEF's data indicates that coal units that operated at a net loss for 5 of the 6 years between 2012-2017 had an average annual loss of $16 million dollars. By 2030, it is assumed 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 6 years from 2012-2017 would close between 2025 and 2030. Based on the historic trend, these units would have a net loss for 13 years straight. These projections are within the range of what is projected in other models such as EIA's AEO (63 GW by 2025 and 70 GW by 2030) and Rhodium Group's Taking Stock 2018 (80 GW by 2025) and BNEF NEO which projects 144 GW by 2030.

Renewable Energy Generation

At the federal level, the renewable energy PTC and ITC are included in the GCAM baseline through their current phase-down schedules and thus incorporated into the *Current Measures* scenario by default. The state, city, and business actions described below, by contrast, are modeled explicitly in ATHENA as a part of the sectoral analysis before being fed as inputs to GCAM and ultimately incorporated into the *Current Measures* scenario. The process for estimating these state, city, and business actions is described below.

STATE RENEWABLE ENERGY DEMAND

All 29 currently mandated RPS policies in the U.S. plus the District of Columbia's target were included in the existing actions category, while four non-binding Renewable Portfolio Goals (RPGs) were also included in the pledged actions category in the *Current Measures* scenario.[20] In order to determine the impact of RPS policies on renewable (RE) deployment, the RE demand driven by the policies was estimated, while accounting for demand that would be met from both hydroelectric and non-hydroelectric sources (e.g., wind, solar, and biomass). The analytic team used state electricity load forecast estimates 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 1990-2016. State-level electricity load forecasts (for the years 2017-2030) were then calculated by applying annual growth rates from GCAM's state electricity demand outputs to the baseline EIA data.

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 and/or compliance exclusions for certain categories of load-serving entities (LSEs). We obtained effective RPS demand rates (for the years 2017-2030) from data and analysis provided by the Lawrence Berkeley National Laboratory (LBNL). We then applied these state-level effective RPS rates to the above-mentioned, GCAM-derived state load projections to generate annual renewable energy demand estimates (GWh of renewable generation required to meet the mandate). Analyses from NREL and LBNL on historic REC procurement in the RPS market by fuel type were used to estimate the share of RPS demand that would be met from hydroelectric vs. non-hydroelectric generation for each state.[21]

For states with non-binding RPG policies (for which LBNL does not publish estimates), we produced annual RPG rate projections (for the years 2017-2030) by assuming a linear progression toward their goals starting from 2016 baseline renewable energy mix (percentage of load generated from renewables), derived from GCAM inputs. An assumption was made that any pre-existing hydroelectric generation within the state would be used to meet these goals, while all future renewable energy demand resulting from the goals would be met with non-hydroelectric sources.

CITY RENEWABLE ENERGY DEMAND

For city commitments, we estimated the impact of 104 currently-pledged RE targets (e.g., a city goal of generating 100% of its electricity from renewables). Impact was quantified in terms of renewable energy demand (in GWh), derived from city load forecast estimates and city renewable energy target data (percentage of electricity load required to meet goals).

We obtained city-level electricity load estimates from the SLED tool, which contains city-level GHG inventory activity data estimates for over 23,000 incorporated towns and cities in the U.S. SLED electricity consumption estimates by city (in MWh) for the year 2013 were projected forward through 2016 using actual state-level electricity consumption growth rates derived from EIA. The city-level consumption estimates were then projected forward for the years 2017-2030 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; data prepared by The Cadmus Group; and individual city Climate Action Plans, press releases, and city council resolutions. 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 in-state electricity generation estimates (by fuel type), with the assumption that a) a city electricity load's mix of renewables matches that of its state and b) for the purposes of city-level RE targets, only non-hydroelectric renewable sources would count toward the baseline mix. To calculate annual renewable energy demand for the years 2017-2030, we further assumed that a city's 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 for the years 2017-2030 to generate annual renewable energy demand estimates (gigawatt hours or GWh of renewable energy required to meet the target).

REAL ECONOMY AGGREGATION FOR RE

To account for overlap between city-level targets and state RPS policies, we used a "net percentage/rate" approach. Under this approach, only additional demand from city goals in a given model year is counted and added on to state RPS 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 can be applied to the city's load in order to calculate additional RE demand.

The two primary sets of assumptions associated with this approach are as follows:

1. The approach assumes that all LSEs within a state (i.e., entities, such as utilities, that provide electricity to final consumers) are in compliance with RPS requirements. While LSE boundaries do not align with those of cities, it is assumed that aggregate compliance is smoothed out across the state, and thus the share of renewables on the grid is not only aligned with the state's RPS goal but is the same from one city's territory to the next. City demand that exceeds the ambition of state goals is then assumed to be additional rather than being dampened by potential non-compliant LSEs. This set of assumptions is based on historic RPS achievement on the part of states and LSEs as well as consultations with experts at both NREL and LBNL, with the caveat that it is intended only for the sake of estimating demand in aggregate and doesn't reflect the nuances of many local electricity markets.
2. The approach further assumes that city-wide targets are met with a combination of a) baseline renewable energy generation (e.g., generation already required to meet RPS compliance) and b) additional procurement, whether through local generation, utility contracts, or some other mechanism. In other words, the renewable energy demand resulting from city targets is not entirely additional to RPS demand, and is first met with the same renewable energy credit (RECs) and underlying generation used for state RPS compliance before being "topped-off" with additional procurement to reach the target renewable energy mix. 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. The assumption that demand resulting from city-level targets is not entirely additional to state RPS demand is based on consultations with experts, with the understanding that it is intentionally simplistic, may not reflect the on-the-ground reality for a specific city's context, and is intended only for the purposes estimating impact in aggregate.

We heard from 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 RE target, 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 LSEs overachieving on their goals and taking advantage of changing economics, irrespective of city goals. The above assumptions represent a

"middle of the road" approach that attributes some demand to city-level targets while assuming considerable overlap with RPS compliance at the same time.

Finally, we also attempted to account for potential overlap between city-level targets and reference case scenario or "economic" renewable generation in states without RPS policies. Our current approach to account for this potential overlap essentially treats state-level reference case renewable generation rates (percentage of renewable generation relative to total generation) – derived from GCAM – in the same way that RPS demand rates are treated in the above description. Thus, reference case renewable generation rates serve as a baseline amount of renewable generation which a city-level target is not entirely additional to. For example, a city with a 60% goal for the year 2022 in a state with no RPS but a 25% renewable generation mix would have a net 35% that can be applied to the city's load in order to calculate additional RE demand.

Building & Industrial Energy Efficiency

STATE ENERGY EFFICIENCY RESOURCE STANDARDS

Twenty-six states have an energy efficiency resource standards (EERS) currently in place, which establish energy savings targets for electricity and/or natural gas use that utilities are required to meet. Nineteen states have binding electricity EERS (which we count in our existing action category) while seven states set a cost-cap or allow certain groups of customers to opt-out of the program (which we count in our pledged action category). Sixteen states have natural gas EERS in place. Utilities can use a range of customer programs to achieve their target like weatherization programs or appliance and equipment rebates. We therefore conservatively assumed the effects of energy efficiency policies other than EERS helped to achieve the state target in our bottom-up modeling.

We obtained state-level commercial, residential, and industrial electricity and natural gas demand data from the EIA (1990-2016). We then estimated annual demand growth rate projections (%) from GCAM's state electricity and natural gas demand outputs (exajoules or EJ) and applied these growth rates forward to estimate baseline state electricity and natural gas demand for states for the years 2017-2030. Under the policy scenario, we applied the average annual incremental electricity and/or natural gas savings target as estimated by ACEEE's 2017 State Energy Efficiency Scorecard[22] 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 natural 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.[23]

CITY ENERGY EFFICIENCY TARGETS

A total of 285 cities were examined for adoption of a relevant energy efficiency target (usually a percentage reduction from historical base year energy consumption). Data sources included ACEEE, which included target data for the top 51 MSAs in the U.S., as well as supplementary data provided by The Cadmus Group in order to expand coverage to all 285 cities with a population greater than 100,000. Of these cities, 38 were identified as having a relevant, quantifiable energy efficiency target. Unless noted otherwise, it was assumed that the energy efficiency target applied to residential, commercial, and industrial energy use.

To estimate the 38 cities' baseline energy use, city-level commercial, residential, and industrial electricity and natural gas demand data was obtained from the SLED tool. 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) and Arlington County, Virginia (which is not captured in SLED).

Projections of activity data are limited at the city level, so this analysis assumes that city energy demand grows at a similar rate compared to state demand, which may or may not be the case on the ground. Because SLED provides estimates for 2013 only, historical city energy demand was estimated for 2005-2012 and 2014-2016 using EIA's state-level electricity and natural gas demand growth rates. Electricity and natural gas demand for 2017-2030 using GCAM's state-level energy demand growth rates. For each city, the TWh of electricity and natural gas savings was estimated based on its specific energy efficiency target. For cities that have targets which apply only to certain sectors, the target was applied only to the proportion of energy demand for that sector only, based on SLED's 2013 sectoral estimates. Note, several cities have targets that required additional assumptions to be made, 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 natural 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.

REAL ECONOMY AGGREGATION FOR EE

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 city targets are additional if that city is serviced by a municipal utility that is exempted from the state's EERS and that 25% of city targets are additional if that city is serviced by an investor-owned utility. 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.[24] Note, this assumption could vary drastically across cities. The result is an estimate of total electricity (TWh) or natural 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.

Vehicle Miles Traveled Reductions

STATE VMT REDUCTIONS

To estimate the impact of state vehicle miles traveled (VMT) reduction targets, information on three state targets (California, Vermont, Washington) was obtained from the ACEEE state policy database.[25] Historical state-level VMT was obtained from the DOT's FHWA Highway Statistics Publications (1990-2016).[26] GCAM's VMT growth rates were used to estimate each state's baseline VMT projections from 2017-2030. While GCAM's VMT projections do not take into account sub-national 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 cities and states VMT-per-capita targets for certain vehicle categories, instead of total VMT reduction targets, we used state-level historical population data and growth projections from GCAM.

For each target, the reduction in VMT between 2017 and 2030 was estimated considering its specifications – whether the 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. VMT was assumed to grow linearly between target years.

CITY VMT REDUCTIONS

According to ACEEE's city policy database, seven out of the 51 cities representing the largest metropolitan statistical areas (MSAs) have quantifiable VMT reduction targets. In addition to these targets, supplementary data provided by The Cadmus Group were relied upon to expand coverage to the top 285 most populous cities in the U.S., resulting in the identification an additional eight city-level targets, for a total of 15. City-level VMT baseline data were obtained from the SLED tool. The SLED tool combines city, state, regional, and national data from DOT and the U.S. Census to create city-level VMT estimates.[27] 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 2016,

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 using GCAM's state-level estimates for 2017-2030. To assess per capita VMT targets, we used U.S. Census data at the city level estimated for 2010 to 2016. For years prior to 2010 and beyond 2016, we used state-level growth rates from the GCAM population baseline to project the city population back from 2010 and forward from 2016. As with state VMT targets, we assume a linear trend in VMT between target years.

REAL ECONOMY AGGREGATION FOR VMT

California and Washington, both of which have a VMT reduction target, also each have one city with a VMT target. However, in most instances, the expected city VMT reductions were not larger than the state's VMT reduction target. One exception is the target for Los Angeles, CA, for the year 2017. This is because reductions from California's state target were not counted until after 2017, when the goal was announced. From 2017 onward, the expected state reductions were greater than the expected reductions from Los Angeles. The VMT reduction impact resulting from the remaining five city targets were all additional and applied to their state baseline projections.

Zero Emissions Vehicle Regulation and Procurement

ZERO EMISSION VEHICLE (ZEV) MANDATE

California's zero emission vehicle (ZEV) program requires manufacturers to produce an increasing number of ZEVs, with the newest regulation covering model years 2018-2025 for light-duty vehicles and regulations staying steady at 2025 levels thereafter.[28] Currently nine other states (Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont) have adopted ZEV targets through 2025.[29] Seven of these states plus California have signed a memorandum of understanding, committing to having at least 3.3 million ZEVs operating on their roadways by 2025.[30] 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 hybrid plug-in 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 electric vehicles.

Estimates of the total number of ZEVs on the road in each state in 2025 were obtained from the Auto Alliance's Advanced Technology Vehicle Sales Dashboard for California, Connecticut, Maryland, Massachusetts, New York, Oregon, and Rhode Island, which is based on the ZEV MOU's target of having 15% of new vehicle sales be ZEVs by 2025.[31] For Maine and New Jersey, we gathered estimates from Global Automakers.[32] California itself has a goal for 2030 set by an Executive Order.[33] For years beyond 2025, it was assumed that the states would continue to sell vehicles to maintain the percentage of market share they achieved by 2025. To disaggregate to the three types of electric vehicles (BEV/PHEV/FCEV), we utilized EIA projections for the relative shares of each vehicle type from the 2018 AEO.

STATE FLEET PROCUREMENT

We identified three states (California, Illinois, Rhode Island) with quantifiable electric vehicle procurement goals that allowed us to estimate the number of ZEVs procured annually. Non-quantifiable goals not included in the analysis constituted goals that have targets for alternative fuel vehicles in general, but which did not clearly specify procurement goals by type (e.g. vehicles that use biofuels and compressed natural gas (CNG), or hybrid vehicles). We obtained state fleet procurement and electric vehicle figures for all vehicle types (light-, medium-, and heavy-duty) for these states from a mixture of state websites and communication with state vehicle procurement officials. For this quantification, we did not include light-duty electric vehicle procurement goals

from California or Rhode Island since we assume those would be captured through the ZEV regulation. For the baseline of total vehicles procured for each year, we used a five-year historical average of total vehicles procured, since procurement can be variable from year to year. Then we estimated, based on the state fleet goals and procurement data, how many vehicles of each type each state acquires annually. We assumed a linear trend from the year enacted until the target year.

CITY FLEET PROCUREMENT

For quantifiable city electric vehicle procurement goals, we gathered city fleet procurement data for all vehicle types (light-, medium-, and heavy-duty vehicles) and electric vehicle target information from city websites and communication with city vehicle procurement officials. For this quantification, we also disregarded the goals of any city that is located in a state that has its own ZEV regulation (ZEVR). Out of 62 cities initially examined, we identified eight cities (Atlanta, GA, Austin, TX, Chicago, IL, Denver, CO, Indianapolis, IN, Los Angeles, CA, New York, NY, Portland, OR) that have light-duty ZEV procurement targets for their municipal fleet. We assume that the ZEVs procured in the cities located in ZEVR states would count toward the ZEVR goals. Out of cities in non-ZEVR states, five cities (Austin, TX, Denver, CO, Atlanta, GA, Chicago, IL, Indianapolis, IN) have quantifiable ZEV procurement targets. Three cities (Madison, WI, Los Angeles, CA, New York, NY) have electric bus procurement targets. We assumed a linear trend 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 assumed that the cities will maintain the target year's EV fleet for future years as well.

REAL ECONOMY AGGREGATION FOR ZEVS

Our methodology for choosing which targets to quantify for each type of policy has no potential overlap in electric vehicle (EV) sales numbers at the state and city level. We did not count state or city fleet procurement goals for states with a ZEV program. City fleet procurement goals are all modeled as additional to state fleet procurement goals since those two types of fleets do not overlap.

Hydrofluorocarbons

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 more potent than CO_2. In 2015, 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.[34] 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.[35] 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. While it is up to the U.S. Congress to ratify and then implement Kigali domestically, real economy actors can move forward on their own.

REFRIGERANT MANAGEMENT

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.[36]

Because GCAM's baseline projections do not include any existing federal or state measures, we first adjusted GCAM's baseline to account for EPA's Section 608 leakage repair requirement. To do

this, we allocated the annual savings estimated by EPA (7.3 Mt CO_2e) to each state based on state population. We then assumed California achieved greater emission reductions as a result of its stronger state standards.

MOVING TO LOW-GWP ALTERNATIVES

Given the uncertainty about the future of 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. We utilized California's estimates of the maximum impact of this regulation for years 2018 through 2030 as depicted in Table 4.[37]

Table 4. Reductions (Mt 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.

CITY HFC MEASURES

City-specific HFC actions were not included in ATHENA.

CORPORATE HFC MEASURES

According to EPA, the average U.S. supermarket emits over 1,500 Mt 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.).[38] GreenChill partners have, on average, reduced their leakage rate by about 44% compared to the average supermarket.[39] As of March 2018, 215 stores are 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. Because these reductions are reported through a voluntary, rather than binding, program, we include them under our pledged action category.[40]

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 Mt CO_2e per year) from 2017 to 2030.[41] For the pledged action category in the *Current Measures* scenario, we 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. We assumed no additional supermarket chains become GreenChill partners and no additional stores become certified.

REAL ECONOMY AGGREGATION FOR HFCS

For our 'current action' category in the *Current Measures* scenario, we included HFC emission reductions resulting from California's refrigerant management program and adoption of some of the phase out rules covered by EPA's SNAP Rule 20. For our pledged action category, we layered in the additional impacts resulting from GreenChill partner and certified stores located in each state, except for California. Here, the state's supermarkets are taking actions that are likely to help achieve California's existing HFC regulations. We further discounted GreenChill savings for each state by accounting for the savings attributed to existing regulations, like EPA's Section 608 refrigerant management standards.

METHANE FROM OIL & NATURAL GAS SYSTEMS

In April 2012, EPA issued federal NSPS (subpart OOOO), which reduced volatile organic compound (VOC) emissions from new, modified, and reconstructed sources and which also reduced methane emissions as an incidental co-benefit.[42] In 2016, EPA amended the NSPS (subpart OOOOa) to explicitly regulate methane emissions. Although OOOOa is currently under review by EPA and has an uncertain future legal status,[43] the analytic team considers it an on-the-books policy for the purposes of *Fulfilling America's Pledge*. Similarly, BLM Waste Prevention, Production Subject to Royalties, and Resource Conservation rule[44] – also under legal review[45] – is considered an existing, on-the-books policy.

Because GCAM does not explicitly model these federal rules in its baseline projections of methane emissions, we incorporated their impact in our bottom-up analysis. To estimate the impact of these policies, we obtained baseline emissions data and projected reductions from analysis provided by the Environmental Defense Fund (EDF). The state-level EDF analysis includes methane emissions reductions under multiple policy scenarios, including a no-policy reference case scenario, a fully implemented federal NSPS scenario (OOOO), a federal revised NSPS scenario (OOOOa), and individual state policy scenarios. To quantify the impact of the above-mentioned federal policies, state-level reductions were calculated as a percentage below reference case emissions using state activity data. 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.

STATE POLICIES

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 reductions. States identified with such regulations included California, Colorado, Pennsylvania, Utah, Ohio, and Wyoming.

To estimate the impact of these six state policies, the above-mentioned EDF analysis was used. 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 multi-scenario analysis allowed for the assessment of state policies on their own as well as the combined impact of state and federal policies.

CORPORATE ACTIONS

In addition to state and federal regulations (which we categorized as existing actions), the analytic team also estimated the impact of voluntary commitments (included in the pledged category) on the part of natural gas companies to reduce methane emissions through EPA's Natural Gas STAR program. The program currently comprises over 100 corporate partners with commitments across the natural gas supply chain. These include efforts to replace pneumatic devices and compressors at gathering sites with low or zero bleed rates 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 EPA's Greenhouse Gas Inventory.[46] These annual reductions are broken out by the natural 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 EPA is 2016. Thus, to estimate continued reductions for the years modeled (i.e., 2017-2030), it was 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, data from EPA's Facility Level Information on Greenhouse gasses Tool (FLIGHT) were used as a proxy to disaggregate reductions to states. Total oil and gas sector methane emissions by process (e.g., production, distribution) and facility location were calculated using the FLIGHT database. The Gas STAR reductions were then allocated proportionally, based on each state's share of national methane emissions from oil and gas facilities, by segment.

REAL ECONOMY AGGREGATION FOR METHANE REDUCTIONS FROM DISTRIBUTION SYSTEMS

Annual reductions in methane emissions resulting from the *Natural Gas STAR program as reported by EPA already account for overlap with federal regulations.*[47] 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.

Agricultural Methane

Manure management practices are one of the largest agricultural sources of methane, emitting nearly 70 Mt CO_2e in 2016 (10% total methane emissions).[48] However, farms can utilize anaerobic digester technologies to convert this waste into biogas (a mix of CO_2, methane, and other trace elements) through decomposition in the absence of oxygen.[49] Biogas can then be either used to generate electricity on site or further processed to create renewable natural gas (RNG). RNG is essentially pure methane and is interchangeable with conventional, fossil-fuel-derived natural gas in any of its uses, including power generation, heating, and as a vehicle fuel.[50] While some states offer incentives to install anaerobic digester technologies (e.g., offering financial incentives or listing biogas as a qualifying fuel for compliance with an RPS, among others), it is difficult to quantify the direct impact of state-level incentives. Therefore, we focused our analysis on measuring the impact of actions that individual farms enrolled in the voluntary federal AgSTAR program are taking to directly address emissions from manure management.

CORPORATE AGRICULTURAL METHANE MEASURES

Anaerobic digester technologies are commercially available today, with 265 digesters currently either operating or under construction on livestock farms.[51] Through its AgSTAR program, EPA maintains a database of basic information on anaerobic digesters installed across the U.S., including the farm's location, operational date, and estimated methane emission reductions in Mt CO_2e per year.[52] For our pledged actions category in the *Current Measures* scenario, we assumed that each digester continues to avoid the same amount of methane each year after its reported operational date, through 2030. We assumed no new digesters are installed and that no existing digesters are retired.

REAL ECONOMY AGGREGATION FROM AGRICULTURAL METHANE

We summed the historical and projected methane savings by each state to estimate the total impact from voluntary farm actions to reduce methane from manure management practices. There were no state or federal actions that overlapped with these.

SUMMARY OF KEY UNCERTAINTIES & LIMITATIONS

While we have endeavored to capture as much activity by real economy actors 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 inter-sectoral changes into account, though these interactions are addressed in GCAM in the phase of the analysis described in the "*Estimating Overall National GHG Implications Using Scenarios in GCAM-USA*" section of this appendix.
- While we made efforts to account for impacts that are already embedded in the GCAM baseline (for example, the amount of policy-driven energy efficiency gains already included in GCAM outputs) that would naturally overlap projections we were using to estimate the impact of a specific policy or target, there remains some uncertainty around the potential for our estimates to be over- or under-estimating impact.
- Additional uncertainty arises from explicitly disregarding Tier 2 policies that are complimentary to the Tier 1 policies we quantified or are at times enacted even in the absence of a top-down Tier1 goal (for example, a city without a renewable energy target may still promote new wind and solar generation through PPAs, siting reforms, or other mechanisms not modeled in this analysis).
- 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 *Climate Action Strategies* Scenario

OVERVIEW OF THE APPROACH

The objective of the *Climate Action Strategies* analysis was to identify a discrete set of opportunities where state, city, and business collaboration could help drive significant emissions reductions by 2025. We developed a process for quantitative and qualitative assessment of potential opportunities based on a set of validation criteria, which were defined by engaging industry experts and then refined by the analytic team. The *Climate Action Strategies* evaluation process was based on the following:

1. Identify: Develop initial concepts based on high-impact opportunity areas.[53]
2. Refine: Refine initial concepts based on existing programs and policies, and to address key market barriers.
3. Validate: Validate concept by evaluating it against defined criteria, and through expert review and input.
4. Strategize: Develop strategies based on expert input and opportunities identified through the validation process.

5. Quantify: Model quantitative impact of refined strategy based on core assumptions and validation with external experts.

Validation Criteria:

- Emissions Impact: Action presents substantial, quantifiable emissions reduction potential by 2025.
- Technical Viability: Technology exists and is deployable at scale in the near term. Include considerations such as maturity of the technology and ability for supply chains to support scaled deployment.
- Economic Viability: Action is economically-attractive and cost-effective. Evaluate cost-effectiveness relative to incumbent technologies; look at cost trends to understand the future trajectory; emphasize initiatives with a viable business model.
- Political Viability: Political support is likely; strong political opposition is unlikely. Evaluate the position of key stakeholders and members of the public.
- Potential for Scaling: Significant momentum and one or more clear standard-bearers are present. Evaluate existing efforts to implement similar actions or policies, including whether there is strong support and energy to move the initiative forward and if existing models are designed to achieve scale.
- Compelling and Innovative: Action presents innovation and excitement potential. Examine whether action in this area can unlock new opportunities for impact and whether it garners excitement from key stakeholders.

The *Fulfilling America's Pledge* analysis identified 10 *Climate Action Strategies* where states, cities, businesses, and other real economy actors can lead on climate action in the near term, defined as the potential for action to begin immediately, with a focus on cross-sector collaboration. These 10 strategies cover every major emissions sector of the U.S. economy, and detailed assumptions for each one can be found in the section below.

Table 6. Sector Modeling Assumptions for the *Climate Action Strategies* scenario

Sector	Climate Action Strategy	Summary Modeling Assumptions
Power	**#1: Double down on renewable energy targets**	▪ States with an existing RPS extend targets through 2025/2030, while states with voluntary targets achieve and modestly expand targets ▪ Additional cities that have signed onto RE pledges and reside in open energy markets achieve 50% RE target by 2030
Power	**#2: Accelerate the retirement of coal power**	▪ Additional uneconomic coal plants close, including plants in traditionally-regulated markets (94 GW by 2025)
Buildings	**#3: Encourage residential and commercial building efficiency retrofits**	▪ 40 additional cities with a population over 100,000 people and are currently engaged in a city energy or climate action network adopt efficiency targets
Buildings	**#4: Electrify building energy use**	▪ Building electrification scales up in the Northeast and Midwest where high-efficiency, all-electric heating and cooling systems are most economic
Transportation	**#5: Accelerate EV adoption**	▪ States, cities, and businesses implement programs and policies that result in EVs comprising 11% of new sales in 2025 (in line with BNEF EV forecasts)
HFCs	**#6: Phase down super-polluting HFCs**	▪ States representing approximately 50% of HFC emissions adopt California's SNAP program ▪ 50% of U.S. supermarkets achieve reductions in-line with average annual GreenChill partner store levels by 2030.
Methane	**#7: Stop methane leaks at the wellhead**	▪ Aspirational policies beyond current standards are achieved in California, Colorado, New Mexico, Ohio, Pennsylvania, Utah, and Wyoming
Methane	**#8: Reduce methane leaks in cities**	▪ Eight states implement policies that would cut their distribution-system emissions by 50% by 2025, equating to a 30% reduction in nationwide distribution emissions.
Natural and Working Lands	**#9:Develop regional strategies for enhancing carbon sequestration on natural and working lands**	▪ California meets and slightly exceed its Natural and Working Lands policy to reach additional sequestration of 30 Mt CO_2 by 2025; other states begin to implement policies that scale sequestration to achieve an additional 30 Mt CO_2, for a total of 60 Mt CO_2 by 2025.
Economy-Wide GHG Targets/Caps	**#10: Form state coalitions for carbon pricing**	▪ 16 states achieve mandatory or stated aspirational GHG targets

SECTOR-SPECIFIC METHODS

Renewable Deployment

The renewables strategy defines the opportunity to ratchet up renewable energy commitments at a time of plummeting solar and wind costs and rapid evolution of energy business models. The modeling assumptions are organized by state and city opportunities.

Specific assumptions for this sector as modeled in ATHENA were as follows:

For states, the assumptions are oriented around RPS policies, building on current commitments and extending targets for several states. This scenario:

- Sets no new targets for California, New York, and Hawaii, since they already have ambitious RPSs relative to other current policies.
- Sets no new targets for Texas and Iowa because they exceeded their targets and both federal incentives and market forces will continue to drive wind expansion in these states beyond what is politically feasible.

Assumes that all other states with existing RPSs that extend through 2025 or beyond achieve an RPS target that is five percentage points higher than their 2025 target under the *Current Measures* scenario. These states then increase renewable requirements by 2 percentage points per year thereafter through 2030. Exceptions include:

  - Washington, D.C., where a five percentage point increase from *Current Measures* is achieved in 2025, but the District then reverts to its *Current Measures trajectory toward a 50% by 2032 target. This is a more rapid increase than what would otherwise be modeled through the Climate Action Strategies.*
  - Massachusetts, where the RPS increases by 2.5 percentage points annually between 2020 and 2025 and then 2 percentage points per year thereafter.
  - Rhode Island, where the RPS increases by 2 percentage points per year through 2030

- For all states with RPSs that expire before 2025, the RPS would be extended to 2025, increasing at 1.5% percentage points per year. After 2025, it would increase by 2 percentage points per year through 2030.
- For all states that have voluntary renewable portfolio goals (RPGs), these states would meet their goals and – if the goal is met prior to 2030 – continue to increase renewable penetration by 0.35 percentage points each year thereafter. (This intentionally modest annual increase is assumed once the goal is met, since the achievement of the goal is already deemed a relatively high level of ambition on its own.)
- Finally, for states that have no RPS, there would be no additional RE demand beyond market forces.

For cities, this scenario assumes that – in addition to the cities achieving commitments in the *Current Measures* scenario – 100 additional cities would source 50% of their energy from renewable sources by 2030. The 100 cities were selected for inclusion in the scenario based on the following criteria:

- Have not already adopted an RE target (since this is already included in *Current Measures)*
- Have signed onto at least one of the following coalitions: City Energy Project, Urban Sustainability Directors Network, C40, or Sierra Club's Mayors for 100% Clean Energy. These coalitions were chosen because they have active implementation campaigns oriented around achieving increased renewable energy demand

- In addition to the above, have at least one of the following characteristics:
    - Reside in a state with community choice aggregation, a system under which individual consumers within a given jurisdiction can combine their power purchases
    - Reside in a state with retail choice

We assumed a linear scale-up between current RE levels and 50% RE by 2030 in these cities, starting in model year (MY) 2020. In addition, assumptions regarding the additionality of these policies and their overlap with state level goals followed the same logic that was applied regarding city level targets in the *Current Measures* scenario.

Coal Retirements

The *Climate Action Strategies* scenario models what is possible with greater real economy actions targeting utilities, plant operators, states, and public utility commissions (PUCs). It assumes that more retirements are possible, especially in deregulated markets, where business and city investment in renewable energy may provide low-cost alternatives to coal and where real economy coordination with states and PUCs may force greater retirements. However, we assumed that more uneconomic coal units in regulated markets would also close. While coal units in regulated markets are more insulated from economic forces, there is opportunity for real economy actors to advocate and work directly with regulated utilities to achieve a cleaner energy supply. This scenario assumes that in 2020, coal plants in deregulated markets that were uneconomic for the last 6 years would retire (by 2020, these units would have been operating at a net loss for 8 years straight). For 2025, this scenario assumes that units in deregulated markets that had net negative long-run operating margins for 5 of the 6 years between 2012-2017 and units in regulated markets that had net negative long-run operating margins for all 6 years between 2012-2017 would close. In this scenario, 94 GW of coal would retire from 2017 levels by 2025. This is a slower rate than the rate of closures over the last three years from 2015-2017, which averaged 15.6 GW per year (which would equate to 109 GW retired by 2025).

By 2030, this scenario assumes that units in deregulated markets that had net negative long-run operating margins for at least 4 years between 2012-2017 would close and units in regulated markets that had net negative long-run operating margins for at least 5 years between 2012-2017 would close. By 2030, 139 GW of coal would have retired from 2017 levels. This is still less than what Bloomberg New Energy Finance (BNEF) New Energy Outlook (NEO) projects would happen under *Current Measures* by 2030 (144 GW).

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

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 building retrofits. In the *Current Measures* scenario, we modeled the impact of 38 city energy efficiency targets. To model the potential for additional action, we identified forty additional cities that could set meaningful energy efficiency targets that can be achieved through a series of building retrofit policies and collaborative programs, including benchmarking and transparency requirements, building challenge programs, and policies that require building upgrades at key trigger points in the building lifecycle.

Specific assumptions for this sector as modeled in ATHENA were as follows:

- To simulate the potential impact of policies such as benchmarking and transparency and building retrofits, we modeled a 10% reduction in building energy use by 2030 in the forty cities identified.

- Assumptions regarding the additionality of these policies and their overlap with state level goals followed the same logic that was applied regarding city level targets in the *Current Measures scenario*.

Buildings – Electrification

A detailed description of the full potential for building electrification is outlined under the *Enhanced Engagement* scenario description. The *Climate Action Strategies* scenario assumes a proportion of the opportunity outlined under the *Enhanced Engagement* scenario is achieved based on where there is stated interest in pursuing electrification and where there is the greatest economic incentive. It is assumed that the 'market potential' – as outlined in recent NREL and NEEP analyses – is achieved in the Northeast and the Midwest regions.[54] For more details, see the analysis assumptions outlined below for the *Enhanced Engagement* scenario.

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

Zero Emission Vehicles

States, cities, corporate fleet owners, utilities, and private sector innovators can take action to substantially increase the rate of EV deployment, particularly when they work together. These opportunities include collaborative actions such as:

- Group procurement to drive down EV costs.
- Promoting EVs through education and vehicle engagement.
- Improving charging infrastructure to accelerate and scale EV adoption.

These state, city, and business actions would help place the U.S. on a path toward achieving accelerated EV deployment in line with the ambitious projections outlined in the BNEF 2018 EV outlook forecast.[55] Our calculations suggest that these real economy strategies could help achieve 1.94 million EVs sold annually in the U.S. by 2025, an additional 850,000 annual EV sales beyond what is planned in current state and city targets.

Specific assumptions for this sector as modeled in ATHENA were as follows:

- To simulate the impact of increased ambition on the part of real economy actors and building off the impact of state-level ZEVR policies included in *Current Measures, we modeled increased penetration of EVs to reach 11% of annual sales by 2025, a rate that is aligned with projections outlined in BNEF's 2018 EV outlook forecast*.

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. A group of sixteen U.S. states and Puerto Rico, organized under the banner of the U.S. Climate Alliance (USCA), announced its commitment to reducing short-lived climate pollutants in June 2018, and adopting California's HFC rules. Collaborative campaigns involving states, cities, and supermarket chains can encourage additional commitments across the supermarket industry.

Specific assumptions for this sector as modeled in ATHENA were as follows:

- Building on the impact of California's SNAP program included in *Current Measures*, for this scenario we assumed that states representing approximately 50% of HFC emissions (including USCA states) adopt an expanded version of the current California SNAP program that includes aerosols.
- At the business level, building on the impact of reductions achieved by EPA GreenChill partners included in the *current measures* scenario, for this scenario we assumed that by 2030 50% of U.S. supermarkets achieve leakage reductions from refrigeration equipment in-line with average reduction levels currently achieved by EPA GreenChill partners (up from the current GreenChill participation rate of 28% of all U.S. stores).[56]
- Assumptions regarding the additionality of these policies and their overlap with other mitigation polices in this sector – both real economy and federal – followed the same logic that was applied in the *Current Measures* scenario.

Methane from Oil & Gas systems – at the Wellhead

The first strategy to address methane emissions is focused on minimizing methane leaks associated with the exploration and production of oil and natural gas. The strategy calls for putting in place regulations or permitting programs to address methane emissions from oil and gas production facilities.

Specific assumptions for this sector as modeled in ATHENA were as follows:

- Building on the impact of current state-level standards included in the *current measures* scenario, we assumed that states including California, Colorado, Utah, New Mexico, Pennsylvania, Ohio, and Wyoming would implement aspirational state-specific policies that go beyond what is currently on-the-books. These policies would allow for the achievement of in-state reductions of up to 50-60% from a reference case scenario by model year 2025, and were informed by analysis and insights shared by experts at Environmental Defense Fund (EDF).

Methane from Oil & Gas systems – in the Distribution System

The second methane strategy is to detect and repair leaks in the natural gas distribution infrastructure found in major cities and urban areas. Real economy actors can revolutionize the way utilities repair and abate leaks through the use of innovative technologies, improved partnerships, and advanced analytic methods such as the commercially viable and groundbreaking approach referred to as advanced leak detection and repair and data analysis (or ALD+).

Specific assumptions for this sector as modeled in ATHENA were as follows:

- Distribution segment emissions reductions are achieved in eight states (California, Michigan, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, and Texas) which together account for approximately 85% of leak-prone distribution infrastructure nationwide.
- The impact of urban leak detection and repair policy innovation was modeled as a 50% reduction to distribution emissions by in each of these states by 2025. As with the above strategy, this reduction potential was based on analysis and insight shared by EDF.
- The analytic team then addressed potential double counting by factoring out the impact of any distribution-segment policies in same states from the *Current Measures* scenario.

Natural and Working Lands

The strategy to address emissions from the land sector outlines how states, cities, and businesses can spark regional initiatives that support carbon sequestration by the nation's forests, croplands, rangelands, and urban forests, as well as in forest and crop soils and harvested wood products, offset approximately 12% of total US GHG emissions in 2016 (EPA 2018). EPA's 2018 GHG inventory is the basis for the baseline estimate of the annual carbon flux in forests, crop and rangelands, and other terrestrial landscapes. For the *Climate Action Strategies* scenario, we build on EPA's land-based carbon sink estimate of -755 Mt CO_2 in 2016 with the following assumptions.

According to California's Natural and Working Lands policy goals, its initial proposed interventions are designed to increase carbon sequestration in California's forests, crops, other lands, and soils resulting in an additional -15 to -20 Mt CO_2 by 2030 (CARB 2018).[57] Under the *Climate Action Strategies* scenario, we assumed that California can exceed these the upper-end of its target by about 10 Mt CO_2, achieving additional carbon sequestration of 30 Mt CO_2 by 2025 and 40 Mt CO_2 by 2030. We further assumed that other states, many of which are already working on policies and programs to further increase carbon stored in ecosystems and reduce losses of stored carbon, will take actions to catalyze additional carbon storage on natural and working lands. We estimated these results in additional carbon sequestration of -30 Mt CO_2 by 2025 and -40 Mt CO_2 by 2030. In total, we estimated that contributions from CA and other states from natural and working land activities and policies equals an additional -60 Mt CO_2 by 2025 and -80 Mt CO_2 by 2030. These assumptions are consistent with regional and national studies of opportunities for cost-effective enhancement of carbon sequestration, such as EPA's landmark 2005 study of cost-effective carbon sequestration opportunities.[58]

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

Carbon Pricing / State GHG Targets

The strategy for this opportunity area is focused on state collaborations to establish legally-enforceable limits on carbon pollution.

To model the impact of this strategy, we assumed that states with existing mandatory GHG targets (those backed by cap-and-trade regimes or other mechanisms and codified into law) and states with aspirational economy-wide reduction targets (those not explicitly backed by mechanisms and promulgated as goals or executive orders) will implement sector-specific policies and programs that enable them to reach interim and long-term GHG reduction goals.

Specific assumptions for this sector as modeled in ATHENA were as follows:

- By model year 2025, states with both mandatory and aspirational targets achieve reductions consistent their goals, assuming a linear progression in annual abatement achieved from base year to target year.
- Details on state-level targets included in the scenario:
- States with mandatory economy-wide GHG targets (e.g., California SB32, Massachusetts Global Warming Solutions Act, etc.).
    - California: 1990 levels by 2020; 40% below 1990 by 2030.
    - Connecticut: 10% below 1990 levels by 2020.
    - Hawaii: 1990 levels by 2020.
    - Maryland: 25% below 2006 levels by 2020; 40% below by 2030.
    - Massachusetts: 10-25% below 1990 by 2020.

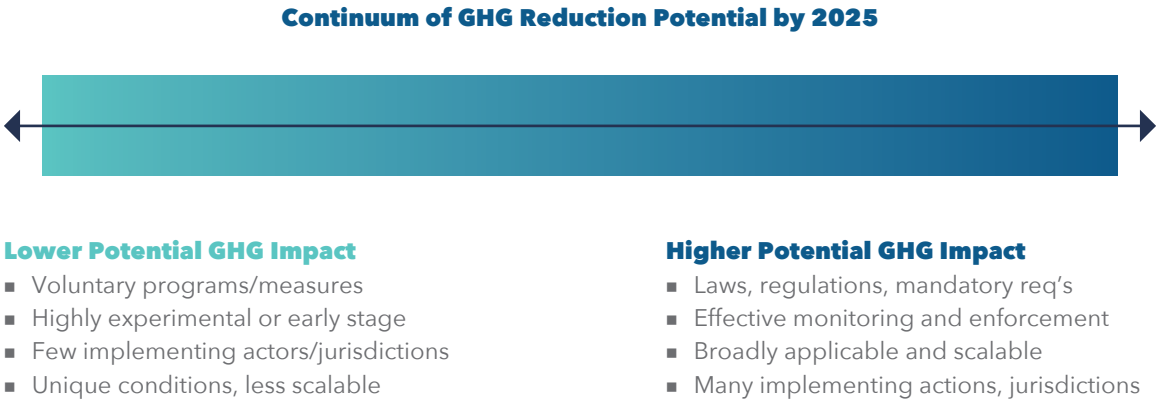
    - New Jersey: 1990 levels by 2020 (statewide GHG plus electricity imports).
    - Rhode Island: 10% below 1990 levels by 2020; 45% below by 2035.
    - Washington: 25% below 1990 levels by 2035.
- **States with aspirational GHG targets** (e.g., by executive order (EO)):
    - Colorado: 26% below 2005 levels by 2025 (EO, statewide GHGs).
    - District of Columbia: 26-28% below 2005 levels by 2025; 50% below 2006 by 2032 (EO).
    - Illinois: 1990 levels by 2020 (EO).
    - Maine: 10% below 1990 levels by 2020 (statutory).
    - Minnesota: 30% below 2005 levels by 2025 (statutory).
    - New Mexico: 10% below 2000 levels by 2020 (EO).
    - New York: 40% below 1990 levels by 2030 (EO).
    - Oregon: 10% below 1990 levels by 2020 (statutory); 20% below 1990 levels by 2025 (target proposed in 2018 legislation, HB4001/SB1507); 45% below by 2035 (HB4001/SB1507).
    - Vermont: 50% below 1990 levels by 2028 (statutory).

Inputs and Assumptions for the *Enhanced Engagement* Scenario

OVERVIEW OF APPROACH

We developed an *Enhanced Engagement* scenario to measure the potential GHG emissions reductions that states, cities, and businesses could achieve if they pursued actions beyond those incorporated in our *Current Measures* scenario and beyond the suite of the 10 *Climate Action Strategies*. Figure 3 below provides an illustration of this concept. It shows that the range of current GHG mitigation actions by real economy actors is a broad continuum – one end of the range represents actions whose likely potential GHG impact by 2025 is lower, e.g., where programs are voluntary rather than required, program characteristics are highly unique and less scalable to other geographies, and/or programs are being implemented by only a few actors/jurisdictions thus far. On the other end of the spectrum are actions with higher potential GHG impact by 2025. These include actions which are driven by law or enforceable policies (e.g., Renewable Portfolio Standards (RPS) and the Regional Greenhouse Gas Initiative (RGGI)), are already being implemented by many actors/jurisdictions, are broadly scalable across new geographies and new jurisdictions, and have immediate impacts on GHGs. The *Climate Action Strategies* are generally focused on building on the momentum of actions from the latter category, i.e., those with high potential GHG impact by 2025. Meanwhile, the *Enhanced Engagement* scenario for 2025 draws from the full spectrum of possible GHG reduction activities across the economy, including measures beyond those included in *Climate Action Strategies* (e.g., agricultural methane reductions).

Figure 5. Continuum of State, City, and Corporate Actions by Potential GHG Impact in 2025



Our estimate of *Enhanced Engagement* adds further ambition to both the actual, on-the-ground progress from current GHG reduction measures implemented by real economy actors and estimates of the additional GHG impact resulting from implementation of the *Climate Action Strategies*. Using that combined GHG reduction estimate (i.e., progress from *Current Measures* plus the *Climate Action Strategies*) as a starting point for *Enhanced Engagement*, we extended ambition towards the upper-boundary of reasonably possible GHG impact for 2025 and 2030. That is to say, for this scenario, we ask what would be feasible using available technologies and practices which are or could be economically viable with strong policy drivers in place or ambitious leadership from the private and public sector. While guided by clear criteria and quantitative considerations, this assessment necessarily involves a measure of judgment. We provide a detailed description of our complete assumptions below.

BUILDING THE ENHANCED ENGAGEMENT SCENARIO

We applied the four key principles below to each major sector or GHG covered in this analysis to develop the *Enhanced Engagement* scenario. The modeling assumptions for this scenario are summarized in Table 7.

1. **The *Enhanced Engagement* started with consideration of three driving factors:**
    - The technical and economic potential for emission reductions for the various sectors, subsectors, and gases by 2025 and 2030.
    - The drivers of those emission reductions (e.g., renewable energy generation or the number of EVs on the road).
    - The policies and actions available to states, cities, and businesses to affect those drivers (including but not limited to those that play a role in the *Climate Action Strategies*).

Our review of key literature depicting economy-wide GHG reduction pathways for the U.S., such as the Mid-Century Strategy,[59] Deep Decarbonization Pathways Project,[60] and leading sector-specific studies from NREL and others provides a range of estimates for total U.S. technical and economic potential, by sector and gas, for 2025 and 2030. This served as the starting point for developing estimates of *Enhanced Engagement*, in many cases possibly providing an upper limit on what *Enhanced Engagement* without federal action might look like, since these estimates typically include federal action.

As we looked across the economy, we identified key metrics that indicate GHG emission reductions in various subsectors, such as changes in TWh of renewable generation, the capacity of retired coal

plants, TWh of energy saved through energy efficiency, the fuel economy of vehicles on the road, and the number of electric vehicles on the road. To the extent possible, we extracted these types of metrics of progress from studies such as the Mid-Century Strategy to understand not just the emission results in those studies, but how emission reductions were achieved across different sectors.

We then considered the degree to which there are policies and actions that can be undertaken by states, cities, and businesses to effect changes across the drivers of emission reductions. In areas where we developed *Climate Action Strategies*, we identified the ways in which the initiatives themselves might be intensified for greater impact, or where other actions outside the initiatives could have impact within the same sector. For sectors or gases where our analysis did not develop specific *Climate Action Strategies* (e.g., agricultural methane), our consideration of policy levers was more qualitative. As part of this more qualitative assessment, we sought to determine whether relevant real economy actors had the capacity to affect the relevant emission-reduction drivers and employed our best professional judgment as to how far *Enhanced Engagement* can reasonably push the drivers of emission reductions.

2. **We assume that real economy actors can be effective at reducing barriers that currently impede the realization of technically- and economically-feasible GHG reduction potential.**

To determine how far beyond the GHG impact of the *Current Measures* and *Climate Action Strategies* real economy actors are likely able to push, we relied upon the team's research into sector- and gas-specific literature for insights on factors that are currently slowing the rate of adoption and penetration of GHG reduction measures. These factors include: industry and market structure; market and political power of key players; the number of actors and decision-makers (e.g., landowners) affected; timeframes for technology stock turnover; and the presence and strength of market and non-market barriers. However, in keeping with our intent that this scenario should capture what could be delivered with increased commitment and resources in the coming years, we took an optimistic view of the willingness and ability of real economy actors to effectively reduce these barriers.

We calibrated the GHG impact by 2025 and 2030 associated with *Enhanced Engagement* based on the number of barriers, strength of policy drivers already in place, and market momentum. Many of the opportunities we considered are already scaling up (e.g., renewables) or appear poised to scale (e.g., building efficiency). However, for sectors which are facing a greater number of factors impeding penetration, and thus have only realized a small percentage of total potential GHG reductions to date, we assumed a lower level of *Enhanced Engagement* for 2025 and 2030.

For example, methane emissions from agriculture (e.g., dairy cows, livestock) accounted for more than 36% of annual U.S. methane emissions in 2016, but GHG reductions have not yet scaled despite the success of pilot programs.[61] EPA's AgSTAR program provides excellent technical support and outreach to participating partners, and agricultural extension programs in leading states (e.g., New York, Vermont, North Carolina)[62] are supporting innovative dairy farmers and ranchers to reduce methane emissions. Despite the potential magnitude of this GHG reduction opportunity from this suite of policies, it lacks a strong policy driver, and only a relatively small set of actors are taking action on a voluntary basis.

3. **We assume that GHG reductions take effect after an appropriate time lag to allow real economy actors to develop policy or program on-ramps that enable GHG reductions.**

While some GHG reduction measures can be established through executive action from a governor, mayor, or CEO, many of the most potent policy approaches, such as an emissions cap or a strong performance standard, need legislative and regulatory support. These approaches require time to generate buy-in among key constituencies and the public, design an effective program, pass enabling legislation, and begin implementation. In the case of a new state policy, such as carbon pricing, a one-year minimum is a reasonable time period for the promulgation and adoption of state-level legislation or rulemaking. As such, we assumed for modeling purposes that GHG emission reductions resulting from many of these opportunities will not begin until late 2019 or 2020.

4. **The *Enhanced Engagement* Scenario considers the total U.S. technical and economic potential for GHG reductions for various sectors and gases, after accounting for estimated GHG impact of our *Current Measures* scenario combined with that of the *Climate Action Strategies*.**

After the initial modeling run, we compared the results of the *Climate Action Strategies* and the *Enhanced Engagement* scenarios. Because the two scenarios were developed somewhat independently, we needed to confirm whether '*Enhanced Engagement*' is, as intended, indeed more ambitious than the *Climate Action Strategies* scenario, both economy-wide and within the sectors and subsectors for which initiatives have been developed.

Table 7. Sector specific modeling assumptions for the *Enhanced Engagement* scenario

Sector	Summary of Modeling Assumptions for Enhanced Engagement
Power	▪ States without an RPS achieve in-state renewable penetration akin to a conservative RPS mandate. ▪ States with RPS achieve increased rates of renewable penetration in 2025/2030. ▪ A greater number of uneconomic coal plants close (128 GW by 2025). ▪ States with existing nuclear capacity retain 6500 MW otherwise scheduled for retirement.
Buildings	▪ States with existing EERS adopt more stringent targets (as much as 2% energy savings per year), and states that have not adopted EERS adopt modest targets (starting at 0.25% per year and rising to 1.75% per year by 2030). ▪ 16 states with natural gas EERS programs maintain their programs through 2030. ▪ Building electrification occurs across the U.S. in line with economic and market potential studies.
Transportation	▪ EV sales exceed forecasts, achieving 13% of new car sales. ▪ State, city, and business policies and programs support a reduction in nationwide passenger VMT by 2% by 2025 and 3.25% by 2030. ▪ States/businesses adopt additional freight VMT targets.
HFCs	▪ States achieve additional reductions equivalent to a 40% reduction from 2013 levels by 2030.
Oil and Gas Methane	▪ Sufficient voluntary action and engagement with stakeholders occurs such that reductions are achieved in three high-emitting states (Texas, Oklahoma, Louisiana) in-line with achievable source-specific best practices.
Agricultural Methane	▪ State incentives and voluntary action by farm owners scale up methane capture to reach 1,000 farms nationally.
Natural and Working Lands	▪ States scale sequestration opportunities, such as reforestation and soil C enhancement, and achieve additional carbon sequestration of 60 Mt CO_2 by 2025.
Economy-Wide GHG Targets/Caps	▪ Additional states achieve reductions comparable to RGGI targets for the power sector and the U.S. Paris Agreement pledge for the transportation sector.

SECTOR-SPECIFIC METHODS AND ASSUMPTIONS

Renewable Deployment

For the *Enhanced Engagement* renewables assumptions, the analytic team modeled increases in state RPS targets beyond those of the *Current Measures* and *Climate Action Strategies* scenarios. However, whereas in the prior two scenarios RPS targets had been modeled explicitly to reflect existing policies or the potential for increases in policy-driven renewable generation, in the *Enhanced Engagement* scenario RPS targets are meant to more broadly reflect heightened engagement from real economy actors, without making specific assumptions about which mechanisms (e.g. state policies, city goals, business goals) would be employed to achieve the rates of renewable penetration modeled. The RPS targets modeled thus serve as a proxy for broader real economy engagement.

Specific assumptions are modeled in ATHENA as follows:

- States with an existing RPS through 2025 or beyond: achieve an in-state annual RPS rate (i.e. share of total electricity load) that is six percentage points higher than projected target in 2025 in the *Current Measures* scenario. After 2025, rate continues to increase by 3 percentage points per year. Exceptions are as follows:
    - Exceptions:
        - For California, we assume the state exceeds its annual RPS target rates from the *Current Measures* scenario by 2 percentage points per year beginning in model year 2025.
        - Vermont and Washington, D.C. retain the annual RPS target rates they have under the *Climate Action Strategies* scenario, as they already bring the states to a relatively ambitious levels of renewable penetration by 2030 and beyond.
        - For Texas and Iowa, we assumed no changes since they exceeded their targets and markets will continue to drive wind expansion in these states beyond what a politically-feasible RPS would generate.
        - Massachusetts maintains the annual RPS target rates it has under the climate actions strategies scenario through model year 2025, but increases by 3 percentage points each year thereafter.
- States with an RPS that expires before 2025: RPS is extended through 2025, increasing at 2 percentage points per year. After 2025, rate increases by 3 percentage points per year.
- States that have a voluntary renewable portfolio goal (RPG) meet their goal and – if goal is met prior to final model year 2030 – continue to increase renewable penetration by 0.5 percentage points each year thereafter. This intentionally modest annual increase is assumed once the goal is met, since the achievement of the goal is already deemed a relatively high level of ambition on its own.
- States without an existing RPS: Will achieve levels of renewable penetration equivalent to an RPS target of 10% by 2025. This should not be understood to suggest that we assumed that all of the remaining states will adopt an RPS, but rather that on average the remaining states achieve this minimum level of penetration.

Power Sector and Coal

This scenario assumed that coalitions would be successful in forcing a greater share of coal generation to retire. By 2020, units in deregulated markets that operated at a net loss for 5 of the 6 years between 2012-2017 would close. For 2025, this scenario assumed that units in deregulated or regulated markets that had net negative long-run operating margins for 5 of the last 6 years between 2012-2017 would close (128 GW retired from 2017 levels by 2025). For 2030, this scenario assumes that units in deregulated or regulated markets that had net negative long-run operating margins for at least 4 years between 2012-2017 would close, reaching 165 GW in retirements by 2030.

Existing Nuclear

Nuclear generation will remain for the foreseeable future an essential component of any effort to decarbonize the U.S. electric grid. Nevertheless, owners of nuclear generation in many states currently face significant economic headwinds, in part due to low prices in wholesale power markets. This scenario assumed that at least 50% of nuclear generating capacity currently subject to an announced or discussed closure will be retained through at least 2030 through a range of state policy actions, including zero-emission credits.

A 2018 MIT Center for Energy and Environmental Policy Research study recently concluded that a total of 21,657 MW of nuclear capacity could be classified as "at risk," meaning either that operators had announced a planned closure or that the possibility of a closure had been publicly discussed.[63] State actions in New York, New Jersey and Illinois already aim to preserve 8,365 MW of that capacity, leaving 13,292 MW of capacity still at risk. We assumed that state action in some combination of three or four additional states leads to the preservation of approximately 50% of still-at-risk capacity. This translates to a loss of no more than ~6,500 MW of nuclear capacity through 2030.

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

Buildings efficiency

Significant, untapped energy efficiency opportunities exist across the country. A 2017 study commissioned by the Electric Power Research Institute (EPRI) found a potential for than 740 TWh of cost-effective electric efficiency between 2016 and 2035.[64] According to the study's authors, these savings amount to 16% of projected baseline retail sales in 2035.

Some jurisdictions already have made significant progress relative to their estimated economic efficiency potential; others have lagged. To construct the *Enhanced Engagement* scenario for energy efficiency, we first divided states by their relative progress to date and then apply varying levels of energy efficiency ambition. We assumed that many of the states who are leaders in deploying strong efficiency programs and have aggressive EERSs will continue to invest at similarly high levels in the future but will see some slow-down in the rate of efficiency gains, as many of the most cost-effective opportunities have already been realized. We therefore anticipate that rate of annual efficiency gains may be higher in states which have not deployed efficiency at scale to date.

Specific assumptions are modeled in ATHENA according to the descriptions below, organized by subcategories of the overall sector:

ELECTRIC EFFICIENCY

For electric efficiency, we rely on EPRI's 2017 benchmarking analysis to assess states' relative progress toward achieving their efficiency potential.[65] This benchmarking analysis examined the percentage of total economic efficiency states would achieve in various future years assuming they continued to accumulate incremental savings at the same rate as the preceding 10 years. We divided these states into three groups based on their progress and future potential and then apply varying levels of enhanced efficiency policy.

For purposes of calculation, we implemented these electric efficiency savings in GCAM as enhanced EERSs. However, we expect that projected gains in energy savings will be achieved through a far broader range of policy levers at all levels of government and civil society. These may include: building codes, energy performance service contracting, and benchmarking and transparency regulations. To account for this broader opportunity and participation in the modeling, we apply the theoretical standards to as much as 100% of some states' electric demand, rather than to the limited subsets to which these policies typically apply.

For states expected to achieve various percentages of total electric efficiency potential by 2025, we assumed the following:

- States on track to achieve 0%-33% of total economic efficiency potential by 2025 – Beginning in 2020, states adopt EERS with an initial annual incremental target of 0.25%, rising to 1.25% by 2025 and 1.75% by 2030 (for modeling purposes, EERS apply to a minimum of 70% of electric sales to capture the potential for efforts by cities and businesses as well).
- States on track to achieve 34-66% of total economic efficiency potential by 2025 – States increase annual incremental targets by 0.25% beginning in 2020 up to a maximum of 2% per year (for modeling purposes, EERS apply to a minimum of 70% of electric sales to capture the potential for efforts by cities and businesses as well).
- States on track to achieve 67%-100% of total economic efficiency potential by 2025 – Existing EERS annual incremental savings targets remain the same (or are extended), but targets are applied to 100% of state electric sales beginning in 2020 to account for sub-state-level efforts.

For all states, we assumed that cost caps and opt-outs are eliminated.

NATURAL GAS EFFICIENCY

To date, states have been slower to adopt natural gas efficiency policies. Currently, only 16 states have EERS applicable to natural gas. For this scenario, we assumed that these 16 states will maintain their current programs through at least 2030. As with electric efficiency, we applied the standard to 100% of sales to reflect the participation of other stakeholders, including cities and businesses in achieving these targets.

For states without existing natural gas standards, we assumed that states representing 50% of currently uncovered natural gas sales adopt standards in line with ACEEE's model legislation beginning in 2020. This hypothetical standard would initially target 0.25% annual incremental savings, rising to 0.75% by 2025 and 1% by 2030. For modeling purposes and to avoid the need to identify specific states, we applied 50% of this standard to 100% of states currently without standards covering natural gas. Given the lead time required to implement various policies, we applied these hypothetical natural-gas-efficiency targets to 70% of retail sales.

BUILDINGS – ELECTRIFICATION

For the *Enhanced Engagement* scenario for buildings, the calculations are based on published electrification impacts by state for single-family housing. For industry, electrification of boilers and process heating are considered. The approach adheres to the industrial sector analysis methods outlined in a study published by the Northeast Energy Efficiency Partnership (NEEP).[66] Specific analysis assumptions for each sector are outlined below.

RESIDENTIAL SECTOR

- The calculations are based on an NREL study completing over 350,000 simulation runs to represent U.S. single family housing energy use.[67] The study presented energy efficiency (and electrification) savings potential by state based on climate, building typology, utility rates, and equipment turnover.
- For our analysis, the NREL study results were extrapolated to include multi-family housing and mobile homes, assuming each of these units use half the energy of average single family home totaling 1700 sq. ft.
- Savings start in 2017, and the full economic potential is assumed to be achieved in 2025. A linear adoption rate is assumed. The economic potential only includes measures with a positive net present value based on a 30-year analysis period at a real discount rate of 3%.
- The measures are based on Electrification Package 2 (see table below).

Table 8. Building Electrification Measures

End-Use Category	Measure Short Name	Measure Description
Space heating	Replace Gas/Propane/Oil Furnace with VSHP	Replace Gas/Propane/Oil Furnace with SEER 22 HSPF 10 Variable-Speed Heat Pump (VSHP) at wear out
Space heating	DHP (replaces gas/propane/oil boiler at wear out) (60%)	Replace Gas/Propane/Oil boiler with ductless heat pump (SEER 27m HSPF 11.5) at wear out (DHP displaces 60% of space heating load)
Space heating	DHP (replaces gas/propane/oil boiler at wear out) (100%)	Replace Gas/Propane/Oil boiler with ductless heat pump (SEER 27, HSPF 11.5) at wear out (DHP displaces 100% of space heating load)
Water heating	Replace Oil/Propane Water Heater with HPWH (50 gal/80 gal)	Replace fuel water heater (55 gal) with electric heat pump water heater (50 gal/80 gal) at wear out
Package	Electrification Package 1	"Synthetic" package combining upgrades related to electrification; assumes DHP displaces 60% of space heating load
Package	Electrification Package 2 (better DHP)	"Synthetic" package combining upgrades related to electrification; assumes DHP displaces 100% of space heating load (no point-source penalty)

Source: NREL

COMMERCIAL SECTOR

- Electrification impacts on space heating and hot water energy end uses are considered.
- Savings are calculated using NREL data for the residential economic savings potential for heating and hot water.[68] The residential savings data are scaled based on the ratio of commercial sector to residential sector energy use for space heating and domestic hot water based on projected energy use from EIA AEO.

INDUSTRIAL SECTOR

- Electrification measures are applied to natural gas boilers and process heating equipment used in manufacturing.
- The industrial energy end use data by manufacturing sector and U.S. Census region are taken from EIA's Manufacturing Energy Consumption Survey (MECS) 2017.[69]
- The regional electrification potential was allocated to each state by considering the portion of natural gas used by industry by the states in each U.S. Census region. This was determined from 2017 SEDS data.[70] This includes manufacturing energy use as well as energy use from agriculture, mining, and construction.

The NEEP study assumes 13% electrification measure saturation by 2035 for impacted non-electric end uses. This translates to a 0.7% annual adoption rate, which was applied in this analysis.

Zero Emission Vehicles

For the *Enhanced Engagement* scenario, we assumed incremental improvement over the BNEF 2018 forecast modeled in the *Climate Action Strategies* scenario, based on a wide-ranging suite of state, city, and business policies, including but not limited to initiatives aimed at facilitating additional EV adoption by residents of multi-family buildings and policies aimed at more rapidly electrifying corporate and municipal vehicle fleets.

Specific assumptions for this sector were modeled in ATHENA as follows.

- We assumed the following increases above BNEF 2018 sales forecasts:
- 5% above forecasts in 2019 and 2020
- 10% above forecasts in 2021-2024
- 15% above forecasts in 2025 and beyond
- Combined, these assumptions yield a BEV/PHEV market share of 13% of new cars in 2025 (versus 11% modeled as part of the *Climate Action Strategies*).

Natural and Working Lands

For the *Enhanced Engagement* scenario, we assumed that a number of states in addition to USCA states initiate programs and activities which increase carbon sequestration on natural and working lands in the coming years; and that these activities combined expand carbon sequestration on natural and working lands by a total additional amount of -100 Mt CO_2 by 2025 and -130 Mt CO_2 by 2030 relative to the reference case. The majority of these activities would take place on privately owned forests, state and municipal forests, urban landscapes, croplands, and inland and coastal wetlands. We apply an uncertainty range of 150 Mt CO_2 our point estimates for the terrestrial carbon sink, which is a similar range to that used in the Second Biennial Report.

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

Hydrofluorocarbons

As a high-end estimate of achievable reductions, we relied upon analysis completed by the California Air Resources Board (CARB) outlining the state's planned measures toward achieving its HFC emission reduction goals.[71] The analysis outlined the state's goal of reducing emissions from this source by 40% by 2030 from a 2013 baseline. The analysis estimated that a combination of measures will be necessary to achieve the target, including the refrigeration management regulations, SNAP program, and the impact of the production and consumption phasedown schedule under the Kigali Amendment to the Montreal Protocol. Given California is the current leader at the state level in targeting reductions from this sector and the 40% goal is seen as achievable only through a combination of policy levers that have yet to be fully adopted in most regions of the U.S., the target was used as the maximum benchmark for achievable reductions in this scenario.

As such, specific assumptions as modeled in ATHENA for this sector were as follows:

- Building off of the *Current Measures* and *Climate Action Strategies* scenarios, all states reach a 40% reduction in HFC emissions from 2013 levels nationwide by model year 2030.

Methane from Oil & Natural Gas Systems

For the *Enhanced Engagement* scenario, we assumed that sufficient voluntary action and coordination with government and business stakeholders occurs such that reductions are achieved in three high-emitting states with no current standards in place (Texas, Oklahoma, and Louisiana). The reductions modeled in these states were based on policies and best practices likely to be implemented in neighboring states that are currently pursuing the adoption of standards. Specifically, these include leak detection and repair (LDAR), replacement of high-bleed pneumatic devices with zero- or low-bleed devices, and the installation of vapor recovery units (VRU) at storage tanks.

While reductions in these states through the above-mentioned activities were seen as achievable in our *Enhanced Engagement* scenario, the scenario does not make any assumptions on specific actors that the implementation would stem from (e.g. from voluntary corporate action, targeted campaigns, or state policy adoption). Rather, the reductions represent achievable best practices that could be particularly impactful given the relatively large share of emissions that these states comprise.

Specific assumptions for this sector were modeled in ATHENA as follows:

- The implementation of best practices through coordinated real economy action was simulated in the three states included in this scenario through modeling significant reductions from the following sources:
    - Onshore production leaks
    - Pneumatic devices
    - Storage tanks
- Together, reductions from these sources result in reductions in total in-state emissions from this sector of up to 38-46% from a reference case projection in 2025 (note: this represents an aggregate percent reduction that includes the impact of federal level policies modeled in the previous scenarios as well).

Note: this scenario was developed in collaboration with oil and gas sector experts at Environmental Defense Fund (EDF).

Agricultural Methane

Anaerobic digester technology is commercially available today, and over 260 digesters are currently operating or under construction on livestock farms, according to data from EPA's AgSTAR program.[72] For the *Enhanced Engagement* scenario, we relied principally on studies of total technical and economic potential for methane reductions in this sector.[73]

With these in mind as an upper limit, we modeled increased adoption of anaerobic digester technology and improvements to livestock feed to cut methane emissions from enteric fermentation. We used the following specific assumptions:

- We assumed about three to four times as many farms will install digesters as under the *Current Measures* estimated for AgSTAR, partially in response to state educational and technical assistance programs. This would lead to a total of roughly 1,000 anaerobic digesters nationally by 2025.
- We assumed that the average digester capacity of the additional farms would be lower than that for current AgSTAR participants because many of the larger farms with the greatest economic potential are already participating. This translated into an average digester capacity for additional farms under *Enhanced Engagement* of approximately 10,000 to 13,000 tons of CO_2e, compared to an average of 23,000 tons of CO_2e for current farms.
- We also assumed that lower-cost livestock feed management strategies will be implemented to reduce methane emissions from enteric fermentation. All told, these trends would result in a reduction of about 15 Mt CO_2e in 2025 relative to the reference case or approximately 10 Mt CO_2e more than estimated under our *Current Measures* scenario.[74]

Landfill Methane

We assumed that all economic landfill gas (LFG) reductions under $20 per ton CO_2e are captured by 2025 (roughly equivalent to 9% below reference case). The additional reductions through *Enhanced Engagement* equal roughly 11.5 Mt CO_2e. We assumed landfill methane emissions continue to fall between 2025 and 2030, reach 11% below the reference case annual emissions of 128 Mt CO_2e in 2030 (a reduction of 14.08 Mt CO_2e relative to the reference case).[75]

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

Carbon Pricing / GHG Targets

While many states have formally adopted goals to reduce economy-wide GHG emissions, in some cases adopting cap-and-trade systems or other binding mechanism to implement their targets, many others in the U.S. have yet to adopt targets. Still, others have joined initiatives to reduce emissions from the power sector (e.g. RGGI states) but have not yet adopted significant goals to reduce emissions from other major emissions sectors such as transportation. Changing politics, efforts by grassroots organizations, and an increasing societal acceptability of pricing carbon could allow for further expansion of emissions reductions targets beyond currently stated goals.

Specific assumptions as modeled in ATHENA for this sector were as follows:

- Six states (Pennsylvania, North Carolina, Ohio, Michigan, and Nevada) achieve power sector emissions reductions consistent with those of RGGI states (38% reduction from 2015 levels by 2030).
- Three states (Pennsylvania, New Hampshire, Delaware) achieve transportation sector emissions reductions of 35% from 2005 levels by 2030 (derived from an estimate of reduction potential from a current policy scenario produced by Georgetown Climate Center).[76]

Note: for subnational carbon pricing/caps, the potential for emissions leakage – i.e., the potential for actors located outside the jurisdictions which have carbon prices or caps to increase energy use and emissions in response to climate action elsewhere – can have offsetting effect on estimated GHG impacts. Our modeling results show limited emissions leakage for states outside the emission caps. This limited leakage is mostly constrained to the power sector; the end-use sectors, such as buildings, industry, or transportation, are impacted less.

Chapter 5: Estimating Overall National GHG Implications Using Scenarios in GCAM-USA

The third step in the *Fulfilling America's Pledge* analysis was the development of estimates of the overall, economy-wide implications of the three scenarios in this study: *Current Measures*, the 10 *Climate Action Strategies,* and the *Enhanced Engagement* scenario. This chapter discusses the process of developing these economy-wide estimates. The first section provides background on GCAM-USA, the primary modeling tool used to calculate economy-wide impacts, using inputs from the sectoral analysis discussed in Chapter 4. The next section discusses how the sectoral information was incorporated into the economy-wide analysis. The final then provides an overview of key drivers of the results and the assumptions used to conduct sensitivity analyses of the economy-wide results.

Overview of GCAM-USA

The estimates of economy-wide emissions results in *Fulfilling America's Pledge* are based on a version of the Global Change Assessment Model (GCAM)[77] with detailed representation of the U.S. energy system at the state level (GCAM-USA). The global version of GCAM is an open-source multi-sector model that represents the energy and economic systems for 32 geopolitical regions, including the United States. It represents agriculture and land use systems in roughly 300 land use regions embedded within the 32 geopolitical regions. GCAM tracks emissions of a range of GHGs and air pollutants based on the energy, agriculture, and land use systems that emerge from any scenario. GCAM is a dynamic recursive model and operates in 5-year time-steps through 2100.

GCAM-USA is a version of GCAM that breaks out the energy and economy components of the U.S. into 50 states and the District of Colombia in addition to modeling the simultaneous interactions of 31 geopolitical regions outside of the United States. GCAM-USA was the primary modeling tool used in the U.S. Mid-Century Strategy. The version of the model used in this analysis was based on the version of GCAM-USA used in the U.S. Mid-Century Strategy, but modified and adjusted throughout the course of this analysis.

The energy system formulation in GCAM-USA consists of detailed representations of extractions of depletable primary resources such as coal, natural gas, oil and uranium, in addition to renewable resources such as bioenergy, hydro, solar, wind and geothermal. Bioenergy production is modeled in several hundred global land use regions 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, and urban land.

GCAM-USA also includes representations of the processes that transform these resources to final energy carriers which are ultimately used to deliver goods and services demanded by end users in the buildings, transportation, and industrial sectors. Key energy conversion sectors such as refining and electric power are modeled at the state-level. The electric power sector includes a representation of a range of power generation technologies including those fueled by fossil fuels (with and without carbon capture, utilization and storage, or CCUS), renewables, bioenergy (with and without CCUS) and nuclear. Technological advancement is by means of decreasing technology costs and increasing efficiencies over time.

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.

GCAM is a market equilibrium model. This means that 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. 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 balances and quantities of the commodities they buy and sell.

Implementing the Three Scenarios in GCAM-USA

The majority of real economy actions were incorporated into the economy-wide analysis in *Fulfilling America's Pledge* by directly altering inputs to GCAM-USA to represent the impacts developed in the sectoral analysis (Chapter 4 above) and then using the outputs directly from GCAM-USA. In these instances, sectoral impacts were converted into metrics (Table 9) that can drive sector reductions in GCAM-USA. As a technical approach to handle the "hand-off", sectoral metrics were aggregated up to the state level for inclusion in GCAM-USA. In most cases, these impacts were applied at the state level in GCAM-USA. 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.

Table 9. Converting ATHENA outputs to GCAM inputs

	Aggregated ATHENA metric	GCAM input metric	GCAM geographic level
GHG targets	$MMTCO_2e$ cap	$MMTCO_2e$ cap	Grid Region
Renewable energy targets	TWh RE demand	% renewable of total electricity load	Grid Region
Energy efficiency target	TWh electricity saved by sector (residential, commercial, and industrial)	TWh electricity saved by sector (residential, commercial, and industrial)	State level
Vehicle miles traveled reduction targets	VMT reduced	% below GCAM baseline	State level
Zero-electric vehicle targets	ZEV sales	# electric vehicle miles traveled	State level
HFC emission standards	$MMTCO_2e$ HFC emissions abatement	% below GCAM baseline	State level
Methane from oil & natural gas systems	$MMTCO_2e$ CH_4 emissions abatement	% below GCAM baseline	State level
Methane from manure management	$MMTCO_2e$ CH_4 emissions abatement	% below GCAM baseline	State level

There were several exceptions to the overall approach for linking the sectoral and economy-wide analyses. CH_4 emissions from oil and gas production and distribution in the U.S. were calculated outside of GCAM-USA. Oil and gas production from EIA's AEO was used to set the activity level, and emissions coefficients were applied to these activity levels for the different scenarios. In addition, 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 the Biennial Report. This difference manifests itself in non-CO_2 projections in GCAM-USA that also differ from the projections in the Biennial Report and other U.S. government analyses. For this reason, and for consistency, GCAM's non-CO_2 emissions outputs were normalized to the Biennial Report history. 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, this sink was assumed to stay at roughly today's levels. Adjustments were made to *Current Measures* scenario to represent more ambitious action in the *Climate Action Strategies* and *Enhanced Engagement* scenarios.

For the *Current Measures* scenario, we assumed full compliance with all policies and commitments, including all pledged actions (which combines the existing and pledged actions) from the sectoral analysis. This was done to recognize that all policies and actions represent stated commitments on the part of the actors—legally binding or otherwise. This analysis does not make assessments about likelihood or probabilities of these policies or actions being undertaken. Table 10 shows the overall set of policies that are explicitly incorporated in the economy-wide modeling. Other trends beyond just these policies are also captured in the assessment.

Table 10. Policies reflected in GCAM-ATHENA integrated modeling of *Current Measures*

Policy Area	Policies explicitly integrated into GCAM-ATHENA
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), 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)
Oil & gas systems	Existing equipment standards (S), Reductions reported through GasStar program (B), New Source Performance Standards (F), Bureau of Land Management Rules (F)
Agriculture	Reductions reported through AgSTAR program (B)

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.

While the *Current Measures* scenario reflects actions that are existing or pledged, the additional two scenarios explore actions that real economy actors might consider taking to increase ambition. The *Climate Action Strategies* scenario assumes full enactment of the complete set of 10 *Climate Action Strategies* while also assuming full implementation of the actions in the *Current Measures* scenario. The *Climate Action Strategies* scenario represents just a subset of potential actions, reflecting the lowest-hanging opportunities across various sectors that could be readily adopted by real economy actors. The *Enhanced Engagement* scenario incorporates the core assumptions and assumes full implementation of the suite of measures described in Chapter 4 above.

For the purposes of developing an estimate of the degree to which the actions in the three scenarios reduce emissions from what otherwise would occur in the future, 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 and ES-4 in *Fulfilling America's Pledge* – is designed to simulate the rate of emission 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 real economy actors 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 been 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. In specific, 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 in Chapter 4), while the former does model new builds where market conditions allow.

Core Assumptions and Sensitivity Analyses

In addition to the sectoral implications of real economy actions, there are other important drivers of overall U.S. emissions over time, such as economic growth, population, fuel prices, and more. The results in *Fulfilling America's Pledge* therefore depend on many assumptions about how the U.S. and the world might evolve over the coming decade and beyond. This includes assumptions about economic activity, population growth, energy technologies like solar cells, batteries, and EVs, fossil fuel prices, and the degree to which natural lands in the U.S. are sequestering carbon. We have constructed a set of core assumptions for each of these that represent reasonable and plausible estimates of what the trends for each of these drivers might look like. When results from a single scenario are presented in *Fulfilling America's Pledge*, they are based on these core assumptions.

There is significant uncertainty, however, in what future policy, economic, and technology landscapes will look like. 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. Therefore, estimating future GHG emissions cannot be considered a precise exercise. We acknowledge that the specific trendlines we have assumed in the core assumptions will in fact turn out to be incorrect. For this reason, understanding how much alternate assumptions about the drivers will matter is an important element of the *Fulfilling America's Pledge* analysis. We have generated a range of sensitivities meant to at least partially capture future uncertainty and thereby to help contextualize the results from our core assumptions. Three sensitivities were taken as the focus of this exercise: 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 *Fulfilling America's Pledge*. When ranges are presented for economy-wide results in *Fulfilling America's Pledge*, they are based on these sensitivities. Table 11 below details both the core assumptions and the sensitivities for our analysis. For comparison, these assumptions and sensitivities are compared in Table 11 against assumptions in the AEO from the U.S. Energy Information Administration (EIA) and the BNEF NEO.[78]

Table 11. Core Assumptions and Sensitivities for Integrated Assessment Analysis[1]

Scenario	Current Measures Scenario	Sensitivity	AEO 2018 Comparison[22]	BNEF NEO 2018 Comparison
Economic Growth	Overall GDP[2] growth at 1.9%/year	1.4%/year (low growth) 2.4%/year (high growth)	2.1% (reference) 1.4%/year (low economic) 2.4%/year (high economic)[13]	2.0% (median) 1.7% (low) 2.3% (high)
Population Growth	Overall population[3] growth at 0.8%/year	No sensitivity	0.7%/year (reference) 0.6%/year (low economic) 0.8%/year (high economic)[14]	0.69% (Med) 0.58% (Low) 0.74% (High)
Fuel Prices	Oil prices[4] grow at 2.5%/year	1.6%/year (high resources) 3.3%/year (low resources)	4.7%/year (reference) 3.3%/year (high resources) 5.4%/year (low resources)[15]	Expect Brent crude oil price to decline out to 2030
	Gas prices[5] grow at 0.8%/year	-4.3%/year (high resources) 4.4%/year (low resources)	4.2%/year (reference) 0.9%/year (high resources) 9.1%/year (low resources)[16]	Gas prices grow at 2.8%/year at the reference
Land Use	Terrestrial carbon sink assumed to be largely unchanged relative to today[6]	Uncertainty[7] set at +/- 150 Mt CO_2e	—	—
Electric Vehicles	Electric LDVs are price competitive with internal combustion engines by 2030[8]	Modeled as explicit policy measures	Sales of electric vehicles grow 11 times by 2030, with decreasing prices[17]	—
Solar Power	Solar PV costs[9] drop to $737/kW by 2025	Modeled as explicit policy measures	Average capacity-weighted LCOE is $59.1 /MWh by 2022[18]	Solar PV costs drop to $737/kW by 2025
Wind Power	Wind turbine (class 5)[10] costs drop to $1357/kW by 2025	Modeled as explicit policy measures	Average capacity-weighted LCOE is $48 /MWh by 2022[19]	Wind Turbine (class 5) costs drop to $1357/kW by 2025
Power Plant Retirements	Coal[11]: 3.4%/year	Modeled as explicit policy measures	Coal[20]: 3.3%/year	See power sector assumptions
	Nuclear[12]: 0.7%/year	Modeled as explicit policy measures	Nuclear[21]: 0.9%/year	See power sector assumptions

Notes:

1. All data, otherwise noted, are from 2015 to 2025.
2. GDP is from Congressional Budget Office (CBO)'s April 2018 report The Budget and Economic Outlook: 2018 to 2028. www.cbo.gov/publication/53651.
3. Population is from Congressional Budget Office (CBO)'s April 2018 report The Budget and Economic Outlook: 2018 to 2028. www.cbo.gov/publication/53651.
4. Oil prices are based on AEO 2018, the growth rate appears smaller because the growth rate is measured between three-year average of 2014, 2015, and 2016, and three-year average of 2024, 2025 and 2026 to avoid abrupt changes.
5. Gas prices are based on BNEF New Energy Outlook 2018, the growth rate appears smaller because the growth rate is measured between three-year average of 2014, 2015, and 2016, and three-year average of 2024, 2025 and 2026 to avoid abrupt changes.
6. Gas prices are based on BNEF New Energy Outlook 2018, the growth rate is between three-year average of 2014, 2015, and 2016, and three-year average of 2024, 2025 and 2026.
7. Land use: Data: U.S. Inventory of Greenhouse Gas Emissions and Sinks. 1990-2016.
8. Uncertainty range: from the Second Biennial Report of the United States.
9. Electric Vehicles are from the United States Mid-Century Strategy.
10. Solar: 2015 based on NREL 2017 ATB Medium Case; 2025 and 2030 from BNEF; 2020 interpolated - UMD analytic team.
11. Wind: 2015 based on NREL 2017 ATB Medium Case; 2025 and 2030 from BNEF; 2020 interpolated - UMD analytic team.
12. Coal is based on EIA and BNEF, retirement trajectory by UMD analytic team.
13. Nuclear data is from the Nuclear Regulatory Commission.
14. GDP: AEO 2018, Appendix B, Table B4. Macroeconomic indicators.
15. Population: AEO 2018, Appendix A, Table A20. Macroeconomic indicators.
16. Oil prices: AEO 2018, Appendix D, Table D1. Total energy supply, disposition, and price summary.
17. Gas prices: AEO 2018, Appendix D, Table D1. Total energy supply, disposition, and price summary.
18. Electric Vehicles: AEO 2018, Data, Reference case.
19. Solar: Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2018, March 2018, Table 1a, Table A1a, Table B1a.
20. Wind: Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2018, March 2018, Table 1a, Table A1a, Table B1a.
21. Coal: AEO 2018, Data, Reference case, Table 9. Electricity Generating Capacity.
22. Nuclear: AEO 2018, Data, Reference case, Table 9. Electricity Generating Capacity.
23. All 2015 data is from AEO 2017, https://www.eia.gov/outlooks/archive/aeo17/tables_ref.php.

Sources: CBO (economic growth), AEO (oil price), BNEF (gas price, RE costs).

Appendix A: Detailed Summary Tables for Sectors and Scenarios

The following section details sector-specific assumptions for each of the three scenarios. For each sector, we provide the activity-driver outputs generated from the sectoral analysis, both those explicitly modeled in ATHENA as well as exceptions where more top-down estimates were fed directly to GCAM without being passed through ATHENA. These activity drivers, such as total TWh of renewable energy generation or GW of coal capacity retired, are subsequently processed in GCAM to yield emissions projections that account for sectoral interactions. Sector subsections also contain summary policy and modelling assumption tables that broadly outline central assumptions and the institutional sources of relevant information.

Table 12. Full set of sector-specific modeling and policy assumptions for the three scenarios in *Fulfilling America's Pledge: Current Measures, Climate Action Strategies*, and *Enhanced Engagement*

Sector	Scenario	Scenario Assumptions
Power	Current	Federal wind and solar incentives through 2020/2022; states achieve RPS targets; 104 cities with RE goals; all announced coal units retire as do uneconomic coal units located in deregulated markets achieving 69 GW of retirements by 2025 from 2017 coal capacity.
	Strategies	Extend and boost state RPS targets through 2025/2030, while states with voluntary targets achieve and modestly expand targets; Additional cities in open electricity markets achieve 50% RE targets by 2030; Additional uneconomic coal plants close, including plants in traditionally regulated markets, such that a cumulative 94 GW retire by 2025 from 2017 capacity.
	Enhanced	States with an RPS set ambitious new targets; States without an RPS adopt a conservative mandate; A greater number of plants operating at a net loss close achieving 128 GW below 2017 installed capacity by 2025. States with existing nuclear plants create policy to ensure that no more than ~6,500 MW of capacity retires through at least 2030.
Buildings	Current	All 26 states and 32 cities with stated efficiency targets meet the target.
	Strategies	40 additional cities with a population over 100k and are engaged in a city energy or climate action network adopt efficiency targets; Scaling building electrification in the Northeast and Midwest regions
	Enhanced	States with existing EERS adopt more stringent targets and states without an EERS adopt modest targets; Building electrification occurs across the U.S. in-line with economic and market potential studies
Transportation	Current	EPA and NHTSA GHG and fuel-economy standards through MY2025; CA and 9 others states implement 2025 ZEVR targets; 8 cities with EV procurement goals achieve target; States and cities (CA, VT, and WA and 7 cities) achieve stated VMT targets
	Strategies	States, cities, and businesses implement programs and policies that result in EVs comprising 11% of new sales in 2025 (in line with BNEF EV forecasts)
	Enhanced	EV sales exceed forecasts achieving 13% of new car sales; State, city, and business policies and programs support a reduction in nationwide passenger vehicle kilometers traveled by 2% by 2025 and 3.25% by 2030; modeling of additional freight targets

HFCs	Current	Federal sect. 608 RMP; California achieves its goals under its March 2018 target, SNAP program, and RMP; Businesses maintain commitments under EPA's GreenChill program
	Strategies	States representing approximately 50% of HFC emissions adopt California's SNAP program
	Enhanced	States achieve additional reductions equivalent to a 40% reduction from 2013 levels by 2030
Oil & Gas Methane	Current	Existing federal standards remain intact; 6 states achieve reduction targets consistent with existing policy; 5 states achieve distribution-system methane reduction targets; Voluntary NaturalGas STAR program continues apace
	Strategies	Aspirational policies beyond current standards are achieved in CA, CO, NM, OH, PA, UT, and WY; Eight states implement distribution-system policies that would cut emissions 50% by 2025
	Enhanced	Sufficient voluntary action and engagement with stakeholders occurs such that reductions are achieved in three high-emitting states with no current standards in place, in-line with achievable source-specific best practices.
Natural & Working Lands and Agriculture Emissions	Current	Land sector carbon sink remains roughly constant through 2030. Over 260 farms and feedlots enrolled in AgSTAR program reduce methane emissions by 5 Mt CO_2 in 2025.
	Strategies	California meets and slightly exceed existing NWL policy to reach additional sequestration of 30 Mt CO_2 by 2025; other states begin to implement policies that scale sequestration to achieve an additional 30 Mt CO_2 by 2025
	Enhanced	States scale sequestration opportunities such that nationally, U.S. reaches additional sequestration of 40 Mt CO_2 by 2025 above Climate Action Strategies scenario, for a total of 100 Mt CO_2 by 2025. Additional farms and feedlots install methane digesters and implement nutrition changes to reduce methane by an additional 10 Mt CO_2 beyond *Current Measures* by 2025.
Landfill Methane	Enhanced	All economic fill gas (LFG) reductions under \$20/ton CO_2e are captured by 2025 (roughly equivalent to 9% below reference case); An additional 2% below reference case of potential LFG emissions are captured between 2025 to 2030, for a total of 11% below reference case of 128 $MMTCO_2e$ in 2030 (14.08 $MMTCO_2e$ in reductions)
Economy-Wide GHG Targets / Caps	Current	Emissions cuts consistent with existing caps: CA with AB-32 and Northeast states with RGGI
	Strategies	16 states achieve mandatory or stated aspirational GHG targets achieve projected reductions
	Enhanced	Additional states achieve reductions comparable to RGGI caps for power-sector and Paris Agreement for transportation sector

Power Generation

RENEWABLE ENERGY GENERATION

Summary Table of Minimum TWh of Demand for Renewable Energy from State, City and Business Policies

Scenario	2017	2020	2025	2030
Current Measures (TWh)	573	698	854	987
Climate Action Strategies (TWh)	—	704	988	1314
Enhanced Engagement (TWh)	—	726	1050	1473

Notes:
- Values do not represent final generation figures included in economy-wide model and are interpreted by GCAM as minimums (e.g. a state's RPS demand could be exceeded depending on cost assumptions)

Renewable Generation Assumptions and Sources

Scenario	Policy & modeling assumptions	Sources
Current Measures	GCAM reference case renewable generation + current state and city demand	GCAM, NREL, LBNL, EIA historic data, The Cadmus Group, supplementary research on specific state and city targets
Climate Action Strategies	Increased state and city renewable goals	Assumptions developed through independent assessment and expert judgment
Enhanced Engagement	Increased generation in select states based on assumed enhanced potential	BNEF, assumptions developed through independent assessment and expert judgment

COAL RETIREMENTS

Summary Table for Coal Plant Retirements in GW of Capacity by Scenario and Year

Scenario	2017 Installed Capacity	2020 (GW Retired)	2025	2030
Current Measures (GW)	265	25 [240]	69 [196]	102 [163]
Climate Action Strategies (GW)	265	37 [228]	94 [171]	139 [126]
Enhanced Engagement (GW)	265	47 [218]	128 [137]	165 [100]

Notes:
- Units of Analysis = GW of retired coal capacity [value in brackets is remaining coal capacity]
- Values are cumulative from 2017 levels

Coal Retirement Assumptions and Sources

Scenario: Coal generation	Policy & modeling assumptions	Source
Current Measures	In 2020, announced retirements based on EIA reporting In 2025 and 2030, additional uneconomic coal units based on long-term marginal costs calculated in BNEF analysis "Half of U.S. Coal Capacity on Shaky Economic Footing" begin to close – starting with units in deregulated markets. In 2025, units in deregulated markets that were uneconomic for 5 of last 6 years close. In 2030, coal units in any market that had net operating losses for last 6 years.	EIA, BNEF, EIA AEO, Rhodium Group "Taking Stock 2018," IEA WEO, BNEF NEO, Sierra Club
Climate Action Strategies	In 2020, coal units in deregulated markets that are uneconomic for last 6 years retire; in 2025, coal units in deregulated markets that uneconomic for 5 of last 6 and coal units in regulated that were uneconomic for last 6 years; in 2030, units in deregulated markets that were uneconomic for 4 of last 6 years and units in regulated that were uneconomic for 5 of last 6 years.	See references above
Enhanced Engagement	In 2020, coal units in deregulated markets that were uneconomic for 5 of last 6 years; in 2025, all units uneconomic for 5 of last 6 years; in 2030, all units uneconomic for 4 of last 6 years	See references above

NUCLEAR GENERATION

Under the *Enhanced Engagement* scenario, we assumed that no more than 6,500 MW of existing nuclear capacity retires between now and at least 2030.

Buildings

ELECTRICITY DEMAND

Summary Table for Projected U.S. Electricity Demand in TWh of Retail Sales by Scenario and Year

Scenario	2017	2020	2025	2030
Current Measures	3,790	3,870	4,021	4,037
Climate Action Strategies	3,790	3,870	4,018	4,020
Enhanced Engagement	3,790	3,867	3,986	3,883

Notes:
- Units of Analysis = TWh, includes retail sales for all sectors.
- Accounts for potential double counting and embedded efficiency within the GCAM baseline

Electric Efficiency Scenario Assumptions & Sources

Scenario	Policy & modeling assumptions	Source
Current Measures	State EERS, city targets	ACEEE, NREL SLED, EIA, GCAM, The Cadmus Group, supplementary research on specific state and city targets
Climate Action Strategies	Expansion of efficiency measures to 40 additional cities	Assumptions developed through independent assessment and expert judgment
Enhanced Engagement	Expansion of energy efficiency policies and programs based on remaining economic potential	EPRI, ACEEE, assumptions developed through independent assessment and expert judgment

NATURAL GAS DEMAND

Summary Table of Projected U.S. Natural Gas Demand in Trillion Cubic Feet of Retail Sales by Scenario and Year

Scenario	2017	2020	2025	2030
Current Measures (sales, trillion cubic ft)	15.2	15.1	14.9	14.5
Climate Action Strategies	N/A	N/A	N/A	N/A
Enhanced Engagement	15.2	15.1	14.7	14.1

Natural Gas Efficiency Scenario Assumptions & Sources

Scenario	Policy & modeling assumptions	Source
Current Measures	State EERS, city targets	ACEEE, NREL SLED, EIA, GCAM, supplementary research
Climate Action Strategies	N/A	N/A
Enhanced Engagement	Expansion of energy efficiency policies and programs based on remaining economic potential	ACEEE, assumptions developed through independent assessment and expert judgment

BUILDING ELECTRIFICATION

Summary Table of Inputs by Scenario and Year: Savings / Increased Electricity Use

Scenario	2020	2025	2030
Current Measures	N/A	N/A	N/A
High Impact Initiatives Quads: Net [Savings / Electricity Increase]	-0.37 [-0.51/0.14]	-0.84 [-1.15/0.31]	-0.85 [-1.21/0.36]
Enhanced Engagement (Quads: Savings / Electricity Increase)	-0.47 [-0.69/0.22]	-1.05 [-1.54/0.49]	-1.08 [-1.69/0.61]

Notes:
- EIA AEO projects 580 Quads of energy use consumed from residential, commercial, and industrial buildings between 2018 and 2025.
- Electrification of natural gas, fuel oil, and propane heating and hot water systems considered for buildings sector
- Electrification of natural gas boilers and process heating considered for industrial sector
- The values represent cumulative savings up through the reported year

Building Electrification Scenario Assumptions and Sources

Scenario	Policy & modeling assumptions	Source
Current Measures	No current electrification measures	N/A
Climate Action Strategies	Assumes Midwest and Northeast take action in coming years	Assumptions developed through independent assessment and expert judgment
Enhanced Engagement	Full economic potential nationwide	NEEP

Transportation

ZEV

Summary Table of Inputs by Scenario and Year

Scenario	2017	2020	2025	2030
Current Measures (sales)	128,000	213,000	1,150,000	1,999,000
Climate Action Strategies (sales)	N/A	618,000	1,945,000	6,258,000
Enhanced Engagement (sales)	N/A	648,606	2,237,324	7,196,326

Notes:
- Units of Analysis = sales of zero-emission vehicle sales (total of plug-in hybrid, battery-electric, and hydrogen fuel cell)
- Values are annual sales (i.e., number of ZEVs sold in that year)
- Values represent real-world assumptions; actual sales used in the GCAM input metrics are lower due to needing to convert PHEVs into BEVs (assumed to be 1 PHEV= 0.5 BEV). Actual GCAM input metrics converted to additional electric vehicle kilometers traveled.

ZEV Assumptions and Sources

Scenario	Policy & modeling assumptions	Source
Current Measures	ZEVR state targets, state fleet procurement targets, city fleet procurement targets	ACEEE, EIA, GCAM, supplementary research on specific state and city targets
Climate Action Strategies	State, city and business efforts to support rapid adoption of EVs	BNEF, assumptions developed through independent assessment and expert judgment
Enhanced Engagement	Acceleration of efforts to promote EV adoption, including incentives and charging infrastructure as in Climate Actions Strategies but with additional focus on multi-family residences	BNEF, assumptions developed through independent assessment and expert judgment

VMT

Summary Table of Projected Total Vehicle Miles Traveled By Scenario and Year

Scenario	2017	2020	2025	2030
Current Measures (billion VMT)	3,240	3,370	3,580	3,760
Climate Action Strategies (billion VMT)	3,240	3,370	3,580	3,760
Enhanced Engagement (billion VMT)	3,240	3,345	3,525	3,689

Notes:

- *Enhanced Engagement* applies VMT reductions to all types of vehicle miles and preserves current measures where they are more aggressive than broadly applicable *Enhanced Engagement*

VMT Assumptions & Sources

Scenario	Policy & modeling assumptions	Source
Current Measures	State VMT targets, city VMT targets	ACEEE, FHWA, NREL SLED, GCAM, EIA, DOT, The Cadmus Group, supplementary research on specific state and city targets
Climate Action Strategies	N/A	N/A
Enhanced Engagement	States pursue a broad suite of actions including pricing, particularly of parking and travel; infill development; transportation investments, including pedestrian, bike and transit; and transportation demand management.	California legislative analysis of potential VMT reduction approaches; MA Clean Energy and Climate Plan 2020; GCC/Cambridge Systematics, assumptions developed through independent assessment and expert judgment

HFCs

Summary Table of HFCs Inputs by Scenario and Year

Scenario	2017	2020	2025	2030
Current Measures	-7%	-8%	-9%	-11%
Climate Action Strategies	N/A	-12%	-15%	-18%
Enhanced Engagement	N/A	-13%	-25%	-42%
Notes: Units of Analysis = % below reference case (U.S. total)				

HFCs Scenario Assumptions & Sources

Scenario	Policy & modeling assumptions	Source
Current Measures	EPA Sect. 608, CA refrigeration mgmt., CA SNAP, GreenChill supermarket reductions	GCAM, EPA, CARB, WRI CAIT
Climate Action Strategies	Broader adoption of state-level SNAP standards in-line with California's goals + broader supermarket participation in HFC reduction commitments in-line with EPA GreenChill program	EPA, CARB, assumptions developed through independent assessment and expert judgment
Enhanced Engagement	Assumed sufficient state and local action to achieve 40% reduction from 2013 levels by 2030 in all states	CARB, EIA, assumptions developed through independent assessment and expert judgment

Oil & Natural Gas Systems

Summary Table of Projected Oil & Gas Emissions Projections in Mt CO_2e by Scenario and Year

Scenario	2017	2020	2025	2030
Current Measures	-11%	-23%	-32%	-38%
Climate Action Strategies	—	-25%	-38%	-43%
Enhanced Engagement	—	-35%	-44%	-47%
Notes: Units of Analysis = % below reference case (U.S. total) Estimated policy impacts derived in part from analysis conducted by EDF				

Oil & Gas Scenario Assumptions & Sources

Scenario	Policy & modeling assumptions	Source
Current Measures	Federal NSPS and BLM regulations. State policies in CA, CO, PA, UT, WY, OH. EPA Gas Star reported reductions.	EDF, EPA, EIA, independent analysis
Climate Action Strategies	Assumed achievement of aspirational state policies for upstream sources. Assumed achievement of urban methane leak reduction program.	EDF, assumptions developed through independent assessment and expert judgment
Enhanced Engagement	Assumed further reductions in high-emitting states through coordinated action from businesses, local campaigns, and state governments.	EDF, assumptions developed through independent assessment and expert judgment

Agricultural Methane

Summary Table of Agricultural methane emissions in Mt CO_2e by Scenario and Year

Scenario	2017	2020	2025	2030
Current Measures	247	251	259	267
Climate Action Strategies	N/A	251	259	267
Enhanced Engagement	247	251	249	252

Notes:
For manure management, *Enhanced Engagement* increases the number of farms represented in Current Measures reductions from manure management, which generated 10 percent of U.S. methane emissions in 2016. The topline numbers here reflect total agricultural methane emissions, which are expected to rise about 8% between 2017 and 2030.

Agricultural Methane Emissions Scenario Assumptions & Sources

Scenario	Policy & modeling assumptions	Source
Current Measures	Current participants in voluntary AgSTAR program create methane reductions of 5 Mt CO_2e by 2025	EPA
Climate Action Strategies	Same as Current Measures	—
Enhanced Engagement	Three to four times as many farms will participate in the AgStar program, reflecting state programs. This would increase biogas systems to 1,000 nationally by 2025; lower-cost livestock feed management strategies will be implemented to reduce emissions from enteric fermentation. We estimate a total annual reduction of about 15 Mt CO_2e in 2025 (inclusive of Current Measures).	EPA, WRI, assumptions developed through independent assessment and expert judgment

Land Use

Summary Table of Land Use Inputs by Scenario and Year

Scenario	2017	2020	2025	2030
Current Measures	-755	-755	-755	-755
Climate Action Strategies	-755	-755	-815	-835
Enhanced Engagement	-755	-755	-855	-895
Notes: Units of Analysis = Mt CO_2e. Note that these are point estimates and do not yet reflect an estimated range of uncertainty.				

Natural and Working Lands Assumptions & Sources

Scenario	Policy & modeling assumptions	Source
Current Measures	No state or city measures are included in our estimates of Current Measures.	N/A
Climate Action Strategies	CA achieves -30Mt CO_2 by 2025 and -40 Mt CO_2 by 2030. Other states match those quantities of additional C sequestration by 2025 and 2030, respectively.	Assumptions developed through independent assessment and expert judgment
Enhanced Engagement	Additional states join in and further expand their NWL programs, for a total of -100Mt CO_2e by 2025, and -140 Mt CO_2 by 2030.	Assumptions developed through independent assessment and expert judgment

Carbon Pricing

Summary Table of Carbon Pricing Inputs by Scenario and Year

Scenario	2017	2020	2025	2030
Current Measures	N/A	N/A	N/A	N/A
Climate Action Strategies	32	116	350	536
Enhanced Engagement	32	130	386	590
Notes: Units of Analysis = Mt CO_2e abated (U.S. total)				

Carbon Pricing Scenario Assumptions & Source

Scenario	Policy & modeling assumptions	Source
Current Measures	Achievement of current RGGI caps and CA AB32 / SB32	GCAM, assumptions developed through independent assessment and expert judgment
Climate Action Strategies	Set of 16 states + DC achieve GHG reduction targets	EDF, assumptions developed through independent assessment and expert judgment
Enhanced Engagement	Set of additional states achieve power sector reductions comparable to RGGI states and transport sector GHG reductions in-line with Paris Agreement and achievable reductions in modest investment scenarios.	EDF, GCC, assumptions developed through independent assessment and expert judgment

Appendix B: Data and Methodology: Real Economy Entities with GHG Targets & Networks Supporting the Paris Agreement

This section describes the methodology and and data sources for the updated footprint analysis. This analysis depicts the population, GDP or market cap, and emissions for real economy entities with GHG targets (results shown in Table 13, below) and for networks of real economy entities supporting the Paris Agreement (shown in Table 14).

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, Rocky Mountain Institute, and World Resources Institute for the *America's Pledge Phase I Report*.

Real Economy Entities with GHG targets

This portion of the analysis documents the number of real economy 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 13. Entities Committing to GHG Emission Reduction Targets

	Number of Actors	Population (U.S. Census est. July 2017) / Enrollment (for universities)	% of national population (est. July 2017)	GDP (US$M - BEA est. 2016/2017)	% of national GDP - BEA 2017 est.	Market Cap (US$M) 6/1/2018	Reported emissions ($mtCO_2$) - 2016/2017	% of national emissions - EPA 2016	Emissions (with estimates - Mt CO_2e)	% of national emissions - EPA 2016
States	21	174,736,785	53.10%	$11,239,364	57.28%	—	2,492,762,234	38.28%	—	—
Counties	8	7,790,635	2.37%	$612,080	3.12%	—	2,550,886	0.04%	83,943,650	1.29%
Cities	142	52,686,930	16.01%	$3,700,793	18.86%	—	470,104,240	7.22%	571,028,286	8.77%
Combined States, Counties, & Cities	171	194,007,360	58.96%	$12,459,221	63.49%	—	2,730,673,798	41.94%	2,776,714,882	42.64%
Businesses & Investors (All reporting emissions in the US)	1361	—	—	—	—	$25,897,537	1,031,214,101	15.84%	—	—
Businesses & Investors (US-based only)	788	—	—	—	—	$17,787,487	876,163,738	13.46%	—	—
Universities (2017 & 2018 Second Nature)	589	5,349,441	1.63%	—	—	—	25,487,669	0.39%	—	—

Number of Entities: For states (including Puerto Rico), the count of entities that have publicly announced or recorded a GHG emissions target is through CDP, C2ES, or Under2MOU. For counties and cities, the count of entities that have recorded or announced a GHG emissions target are through CDP, Under2MOU, carbon*n*, or ACEEE. For businesses, the counts of entities that have reported both emissions in the U.S. and a climate action are through CDP, Science-Based Targets Initiative, or the CDP's Power Forward 3.0 report. For universities, the count of entities that have registered a climate or carbon commitment is through Second Nature. "Combined States, Counties, & Cities" aggregates the number of states, counties, and cities that have adopted a GHG target.

Sources: CDP disclosure platform for companies and cities 2016 and 2017; CDP/TCG Compact of States and Regions 2016 and 2017; Center for Climate and Energy Solutions, "Greenhouse Gas Emissions Targets," September 2016; "Under 2 Coalition" 2017; carbon*n "Reporting Entities" 2010-2017; American Council for an Energy-Efficient Economy "State and Local Policy Database" 2017; Science Based Targets "Companies Taking Action" 2017*[79]; WWF, Ceres, Calvert, and CDP, "Power Forward 3.0"[80]; Second Nature Presidents' Climate Leadership Commitments 2017 and 2018.[81]

Population: Sum of 2017 U.S. Census estimates as of July 1st for entities with a GHG target in each sub-national actor category: states, counties, and cities. Percent of U.S. total calculated based on 2017 U.S. Census estimate for total population of U.S. states (including the District of Columbia and Puerto Rico) as of July 1st. "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 with targets located in a state that also has a target, and cities with targets located in a county that also has a target. Sum of enrollment figures for universities provided to Second Nature in 2017 and 2018.

Sources: U.S. Census estimates for July 1st, 2017; Second Nature Presidents' Climate Leadership Commitments 2017 and 2018.

GDP: For states, sum of 2017 Bureau of Economic Analysis (BEA) data, and for counties and cities, sum of estimates based on BEA 2016 data. Cities GDP estimated for all counties and cities by multiplying the GDP of the corresponding MSA by the ratio of county or city population to MSA population. This provides a reasonable approximation of county- or city-level GDP and is more appropriate to use than GDP for the full MSA.

Percent of U.S. total calculated based on sum of BEA GDP figures for U.S. states (including the District of Columbia) in 2017 and the predicted GDP of Puerto Rico in the "Economic Report to the Governor" 2017. "Combined States, Counties, & Cities" aggregates the GDP of states, counties, and cities that have adopted a GHG target, adjusting for double counting by excluding cities and counties with targets located in a state that also has a target, and cities with targets located in a county that also has a target.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis "Gross domestic product (GDP) by state (millions of current dollars)", 2017: Q4; U.S. Department of Commerce, Bureau of Economic Analysis "Gross domestic product (GDP) by metropolitan area (millions of current dollars)", 2016[82]; Government of Puerto Rico, Office of the Governor, "Economic Report to the Governor and to the Legislative Assembly" 2017, pg. 5.[83]

Market Capitalization: Sum of the market capitalization figures for June 1, 2018 available through Bloomberg Terminal for all businesses reporting emissions in the U.S. in their 2016 or 2017 CDP disclosure. This figure captures 853 of 1361 actors, with most of the missing values from private or subsidiary companies. These figures are not localized and represent the total market capitalization of companies' global operations.

Source: Bloomberg, June 1, 2018.

Emissions: Sum of 2016 gross emissions where available and estimated 2016 gross emissions for entities in each coalition. Percent of U.S. total calculated based on EPA U.S. gross emissions (including the District of Columbia and all territories) in 2016 (most recent available year).

State and territory emissions are compiled from three sources:

- Responses to the 2017 CDP states and regions questionnaire, when available;
- Estimates based on the World Resources Institute's CAIT Climate Data Explorer 2014 data, which were adjusted to 2016 figures by measuring year-on-year sectoral changes at the national level (based on EPA Inventory of U.S. GHG Emissions and Sinks data for non-electricity sectors and EIA Monthly Energy Review data for the electricity sector) and extrapolating to the state level; and
- EIA for total CO_2 emissions of Puerto Rico in 2015 (most recent available).

City emissions data are for 2016 and were sourced first from CDP 2016 and 2017 cities questionnaires, and second from the carbon*n* registry for emissions reported from 2010–2017 where CDP data were unavailable. Where reported data were unavailable, SLED estimates adjusted based on the 2016 EPA U.S. gross emissions figure were used for city emissions. For businesses and investors, emissions include scope 1 emissions for the U.S. only, based on 2016 and 2017 CDP response data. Business emissions figures are included for 1141 of 1361 companies. "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 with targets located in a state that also has a target, and cities with targets located in a county that also has a target. Sum of emissions figures for universities provided to Second Nature in 2017 and 2018.

Sources: CDP disclosure platform for companies and cities 2016 and 2017; CDP/TCG Compact of States and Regions 2016 and 2017; carbon*n* "Reporting Entities", 2010-2017; World Resources Institute CAIT Climate Data Explorer; U.S. EPA "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016," April 2018; U.S. EIA, "Monthly Energy Review," September 2017; Second Nature Presidents' Climate Leadership Commitments 2017 and 2018; U.S. Department of Energy State and Local Energy Data (SLED).

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 real economy commitment to the Paris Agreement. Two of these coalitions—We Are Still In (WASI) and The Climate Alliance—were formed immediately following the announcement of the U.S. intent to withdraw from the Paris Agreement. The third—U.S. Climate Mayors—was formed upon the adoption of the Paris Agreement in December 2015.

Table 14. Coalitions Expressing Support for the Paris Agreement

	Number of Actors - 8/1/2018	Population (U.S. Census est. July 2017)	% of national population (est. July 2017)	GDP (US$M - BEA est. 2016/2017)	% of national GDP - BEA 2017 est.	Reported emissions ($mtCO_2$)	% of national emissions - EPA 2016	Emissions (with estimates - Mt CO_2e)	% of national emissions - EPA 2016
WASI	2,799	154,729,629	47.02%	$9,620,981	49.03%	1,619,822,965	24.88%	2,007,224,260	30.83%
Climate Alliance	17	133,777,544	40.65%	$9,061,595	46.18%	1,759,685,822	27.03%	—	—
Climate Mayors	412	70,682,484	21.48%	$4,792,978	24.42%	446,793,127	6.86%	769,046,384	11.81%
All coalition members	3036	—	—	—	—	—	—	—	—
Businesses	1779	—	—	—	—	—	—	—	—
Cities	500	73,781,177	22.42%	$4,996,373	25.46%	449,304,392	6.90%	801,723,686	12.31%
Counties	31	26,617,068	8.09%	$1,906,016	9.71%	2,550,886	0.04%	463,108,134	7.11%
Cultural Institutions	31	—	—	—	—	—	—	—	—
Faith Organizations	222	—	—	—	—	—	—	—	—
Higher Education Institutions	343	—	—	—	—	—	—	—	—
Investors	135	—	—	—	—	—	—	—	—
States	17	133,777,544	40.65%	$9,061,595	46.18%	1,759,685,822	27.03%	—	—
Tribes	9	—	—	—	—	—	—	—	—
Combined States, Counties, & Cities	548	173,830,069	52.83%	$11,432,304	58.26%	2,029,791,986	31.17%	2,437,743,996	37.44%

Number of Entities: Sum of the number of entities in each coalition and breakdown of total number of entities that have signed onto at least one coalition as of August 1, 2018. "Combined States, Counties, & Cities" aggregates the number of states and cities that are part of least one coalition. This number is not corrected for double counting – for example, both Duluth, Minnesota (a WASI city) and the state of Minnesota (a U.S. Climate Alliance state) are included in the total.

Sources: We Are Still In, U.S. Climate Alliance, U.S. Climate Mayors.[84]

Population:

Sum of 2017 U.S. Census estimates as of July 1st for entities in each coalition. Percent of U.S. total calculated based on 2017 U.S. Census estimate for total population of U.S. states (including the District of Columbia and Puerto Rico) as of July 1st.

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 in WASI.

Sources: U.S. Census estimates for, July 1st 2017.

GDP:

For states, sum of 2017 BEA data, and for counties and cities, sum of estimates based on BEA 2016 data. Cities GDP estimated for all counties and cities by multiplying the GDP of the corresponding MSA by the ratio of county or city population to MSA population. This provides a reasonable approximation of county- or city-level GDP and is more appropriate to use than GDP for the full MSA.

Percent of U.S. total calculated based on sum of BEA GDP figures for U.S. states (including the District of Columbia) in 2017 and the predicted GDP of Puerto Rico in the "Economic Report to the Governor" 2017.

"Combined States, Counties, & Cities" aggregates the GDP of states, counties, and cities that have adopted a GHG target, adjusting for double counting by excluding cities and counties with targets located in a state that also has a target, and cities with targets located in a county that also has a target.

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.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis "Gross domestic product (GDP) by state (millions of current dollars)", 2017:Q4; U.S. Department of Commerce, Bureau of Economic Analysis "Gross domestic product (GDP) by metropolitan area (millions of current dollars)", 2016; Government of Puerto Rico, Office of the Governor, "Economic Report to the Governor and to the Legislative Assembly" 2017, pg. 5.

Emissions:

Sum of 2016 gross emissions where available and estimated 2016 gross emissions for entities in each coalition. Percent of U.S. total calculated based on EPA U.S. gross emissions (including the District of Columbia and all territories) in 2016 (most recent available year).

State and territory emissions are compiled from three sources:

- Responses to the 2017 CDP states and regions questionnaire, when available;
- Estimates based on the World Resources Institute's CAIT Climate Data Explorer 2014 data, which were adjusted to 2016 figures by measuring year-on-year sectoral changes at the national level (based on EPA Inventory of U.S. GHG Emissions and Sinks data for non-electricity sectors and EIA Monthly Energy Review data for the electricity sector) and extrapolating to the state level; and
- EIA for total CO_2 emissions of Puerto Rico in 2015 (most recent available).

City emissions data are for 2016 and were sourced first from CDP 2016 and 2017 cities questionnaires, and second from the carbon registry for emissions reported from 2010–2017 where CDP data were unavailable. Where reported data were unavailable, SLED estimates adjusted based on the 2016 EPA U.S. gross emissions figure were used for city emissions.

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.

Sources: CDP disclosure platform for cities 2016 and 2017; CDP/TCG Compact of States and Regions 2016 and 2017; carbonn *"Reporting Entities", 2010-2017; World Resources Institute CAIT Climate Data Explorer; U.S. EPA "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016," April 2018; U.S. EIA, "Monthly Energy Review," September 2017; U.S. Department of Energy State and Local Energy Data (SLED).*

Appendix C: Climate Leader Case Studies

The case studies in *Fulfilling America's Pledge* identified impactful climate and clean energy policies as well as the real economy actors that have adopted and implemented those policies. Each case study describes a specific policy type or strategy, profiles a real economy actor's leadership experience with that policy or strategy, and articulates the GHG reductions that have accrued from the implementation of the policy. We selected real economy actors as climate leaders based on a variety of factors including their adoption of ambitious policies, the availability of data on the impacts of those policies, and geographic diversity across the case studies.

Data permitting, case studies also extrapolate the impact of the policies should additional real economy actors adopt them and achieve the same level of GHG reductions as climate leaders. We aimed to project GHG impacts across the following sets of real economy actors:

1. Those real economy actors that have already implemented the policy, and
2. A larger set of real economy actors that have not yet adopted these strategies (e.g., the 100 largest US cities)

The descriptions that follow provide more detail on the methodologies used for extrapolations in each case study.

Case Study One: "Science-based Climate Targets" for Corporations

Science-based targets provide companies with a pathway for aligning their GHG emissions with global targets and warming scenarios by offering a framework for corporate climate strategies that can help companies build long-term business value, safeguard their future profitability, reduce regulatory uncertainty, and demonstrate a commitment to sustainability and innovation to customers and employees.

1. As of May 2018, *seventy-four U.S. companies representing a combined market capitalization of over $2.6 trillion have either set or committed to set science-based targets through the Science Based Targets initiative (SBTi).*
    - The market cap is calculated using the market capitalisation data available from Bloomberg markets.[85] The stock exchanged is derived from the company's HQ country and the units used are millions USD.
2. *U.S.-based companies that have committed to science-based targets as of May 2018 are responsible for an estimated 2 billion metric tons of CO_2e emissions per year across their global operations and value chains.*
    - This includes data on Scope 1, 2 and 3 emissions when available. Scope 1 and 2 emissions were available for 97% of the companies and Scope 3 data for ~70% of the companies. Double-counting due to inclusion of Scope 2 and 3 data is a known issue.
    - For Scope 1 and 2 emissions, CDP 2015 data was used for most of the companies. If CDP 2015 data was not available, CDP data from other years were used and finally, if no CDP data was available, data from sustainability reports or other public sources was available.
    - For Scope 3 data, CDP 2016 Clean and Complete Dataset[86] was used, which includes a combination of modelled and self-reported data.
3. *If all companies in the Fortune 500 were to implement science-based targets, they could reduce the emissions resulting directly from their operations by around 240 Mt CO_2e by 2030, compared to a 2020 base year.*
    - Of the Fortune 500, Scope 1 data was available for 244 companies from the 2017 CDP reporting cycle. To calculate base emissions in 2020, we assumed these 244 companies emitted the same mass of Scope 1 emissions in 2020 as they reported in 2017, and that the remaining 256 Fortune 500 companies emitted half as much, on average, in 2020 as did CDP respondents.
    - We assumed that all 500 companies reduced its emissions by a linear average of 1.23% per year for each year between 2020 and 2025.

Case Study Two: Breaking Barriers to Renewable Energy in Electric Markets

This case study did not include an analytical component.

Case Study Three: Energy Efficiency Resource Standards in Arkansas

The analysis of the Arkansas energy efficiency resource standard and its impacts in Case Study 3 included a review of annual Energy Efficiency Program Portfolio Annual Reports filed with the Arkansas Public Utilities Commission by investor-owned utilities, including Entergy Arkansas and Southwest Electric Power Company. This analysis included a review of program alterations and improvements made on an annual basis in response to challenges and opportunities identified by implementers. ACEEE also tracks annual statewide electric IOU savings as part of the State Energy Efficiency Scorecard, which reports savings as a percent of statewide electric sales data from the Energy Information Administration (EIA). Cumulative annual savings projections in 2020 are the sum of incremental savings beginning the first year of EERS implementation extrapolated to 2020.

Case Study Four: Benchmarking and Transparency Policies for Buildings

This case study focused on Washington, DC, but the estimated reductions in energy and GHG emissions attributed to benchmarking and transparency policies are based on data obtained from buildings complying with New York City's Local Law 84. We used data from New York City because the city's datasets cover more buildings than Washington, DC.

We calculated an energy savings multiplier using building source energy and GHG emission data from 2012 and 2016, the most recent year of available data. While 2012 is not the first available year of reported New York City data, it is the first year that source energy use data were made available to the public. Furthermore, using 2012 data allowed us to include information from more buildings as more owners were required to report data in 2012 than 2011.

Building benchmarking records were joined from the two datasets using New York City's Building Identification Numbers (BINs). While no class of benchmarked buildings were excluded from our analysis, we did remove any records with missing or zero values for energy use or GHG emissions. We calculated the percentage change in energy use intensity (EUI) for the remaining records and removed those with a change in EUI greater than one standard deviation from the mean. The choice to filter records using one standard deviation was made because the value was largely in keeping with findings from other research documenting energy use changes in buildings. We calculated a percentage change in the aggregated energy use and GHG emissions from 2012 and 2016 for the remaining records. Our analysis found that New York City buildings saw a 5% decrease in energy use and 6% decrease in GHG emissions between 2012 and 2016.

Using data from SLED, we applied the New York City multipliers to other cities' relevant energy consumption and greenhouse gas emissions to estimate savings from benchmarking and transparency policies in these places. We first applied these savings assumptions to the energy use and GHG emissions of the 26 municipalities in the US who have already adopted these policies. We then modeled the impacts of these policies should the largest cities in the 100 largest metro regions adopt this policy. We also scaled the energy savings and GHG emissions to the appropriate percentage of the building stock, using SLED data to estimate the energy use and GHG reductions associated with buildings with more than 50,000 square feet of floor space.

Case Study Five: Developing Low-VMT Planning in Portland, Oregon

To estimate the impact of Portland's mode share targets, we used 2015 mode split figures and 2035 mode share goals from the Portland 2035 Transportation System Plan update. Specifically, we conducted a linear interpolation of the sum of the drive alone and carpool share numbers to ramp down these mode shares between 2015 (67%) and 2035 (42.5%).

We then assumed that the impact on annual vehicle miles travelled (VMT) is equivalent to the annual rate of decline (1.23%) in the drive alone and carpool mode share. We applied this rate of decline to a projection of annual VMT for Portland using an estimate of daily VMT for 2015 from the Oregon Department of Transportation as a starting point. To calculate post-2015 daily VMT figures out to 2035 , we applied the average rate of change in VMT between 2010-2015. We then multiplied these daily VMT numbers by 365 days and the projected annual population to arrive at annual numbers.

This allowed us to determine annual savings in VMT from the 2035 target. We then converted these annual savings in VMT to gallons of gasoline savings by assuming that the average on-road fuel economy of vehicles in Portland remains constant at 25 MPG between 2015 and 2035. This leads to the cumulative savings figure of 47 million gallons of gasoline by 2035.

To calculate the impact of similar single occupancy and carpool ride targets on the 24 other cities from the *2017 City Energy Efficiency Scorecard*[87] that currently have targets in place, we started with city-level 2013 total VMT data from DOE's SLED database. We assumed total VMT in those 24 cities stays flat out to 2015 since we have no way of coming up with a projection on historical data. We then applied the same 1.3% annual rate of decline to arrive at total cumulative savings by 2035 of 1.3 billion gallons of gasoline.

- Companies emitted the same mass of Scope 1 emissions in 2020 as they reported in 2017, and that the remaining 256 Fortune 500 companies emitted half as much, on average, in 2020 as did CDP respondents.
- We assumed that all 500 companies reduced its emissions by a linear average of 1.23% per year for each year between 2020 and 2025.

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